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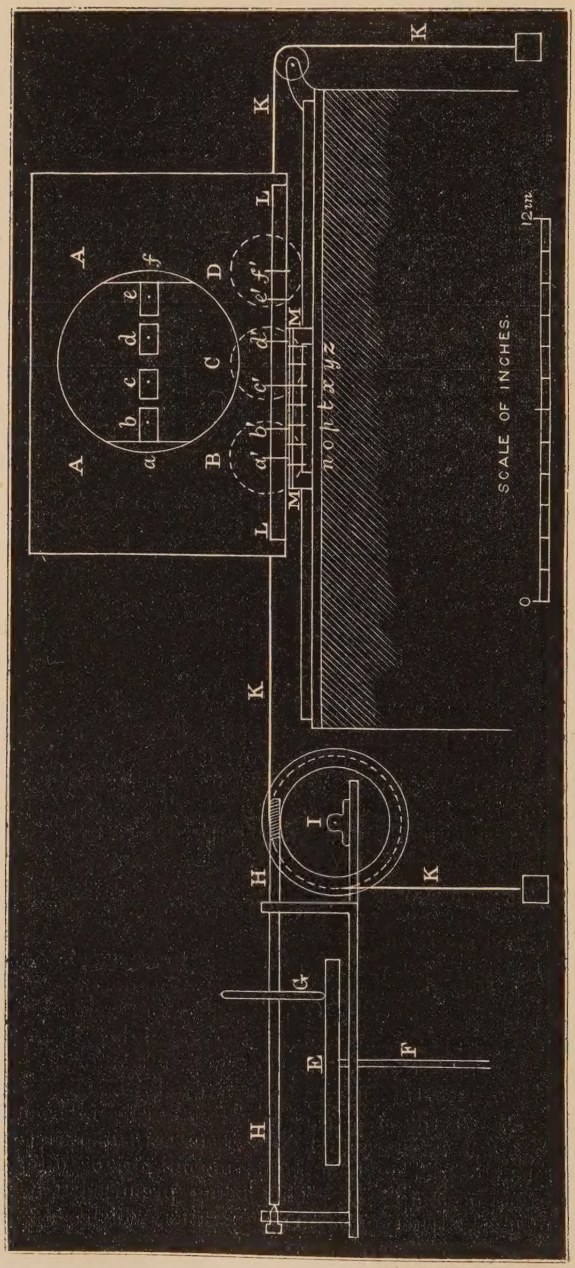
J. W. L. GLAISHER, Sc.D., F.R.S., President, in the Chair.

Thomas Bauchope, East Brucefield, West Calder, Scotland, was balloted for and duly elected a Fellow of the Society.

Description of the Personal Equation Machine of the Royal Observatory, Greenwich. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

This apparatus was planned with a view of determining absolute personal equations, the variations of personal equation depending upon the direction of movement, the velocity, and the magnitude of the star observed, and personality in observations of limbs of the Sun, Moon, or planets. It was arranged that the transit-circle should be used for the determinations, and a point which I specially aimed at was that the conditions of the ordinary observations of the heavenly bodies should be reproduced as closely as possible. Generally speaking, this personal equation machine is on the lines of that devised by M. C. Wolf, and described by him in vol. viii. of the *Annales de l'Observatoire de Paris;* but, as the objects in view were somewhat different, various modifications in the general plan were introduced. Amongst these may be mentioned the much larger dimensions of the apparatus (in consequence of which it is not necessary to use a lens of short focus to form a diminished image of the artificial object), the use of the transit-circle micrometer for adjustment of the contacts to the true transit over the wires, and the use of reflected sunlight, moonlight, or diffused daylight, instead of lamplight. This being premised, I proceed to describe the construction of the apparatus, which was made by Messrs. Troughton & Simms with their usual skill.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An object-glass of $7\frac{1}{2}$ inches aperture, and of about 51 feet focal length, is attached in front of the object-glass of the transit-circle, the telescope tube of the latter being horizontal and pointing north. This long-focus object-glass forms, in fact, a reversed telescope or collimator, in the focus of which is the vertical plate A of the personal equation machine, apertures in which, illuminated by sunlight, moonlight, or diffused skylight reflected from a plane mirror behind, form the artificial objects to be observed. A circular aperture in the plate 6 inches in diameter represents the Sun or Moon, and as only the portions *a*, *f*, near the ends of the horizontal diameter, are required for observations of first and second limbs, the remainder of the aperture is filled by a plate carrying four small pinholes *b*, *c*, *d*, *e* (to represent stars of different magnitudes) adjustable in a horizontal slide. The vertical plate is mounted on a carriage with three grooved wheels (B, C, D) running on two horizontal rails, and carried smoothly by clockwork from east to west, or west to east, at a rate which, by means of an ingenious contrivance devised by Mr. James Simms, may be varied at will from that of a very close circumpolar star to about three times that of an equatorial star. The movement of the vertical plate is effected in the following manner:—A horizontal circular brass plate E is attached to the vertical spindle F of an equatorial driving clock (belonging to one of the photoheliographs), and is thus made to rotate uniformly at a determinate speed. This plate drives by rolling friction a brass disc G, turning about a horizontal axis H, and placed with its rim in contact with the plate. The disc G can be slipped along its spindle and clamped at any point, so that the point of contact of the disc and plate can be adjusted at will to any distance from the centre of the latter, the angular velocity of the disc varying directly as this distance, and changing sign at the centre. At the further end of the spindle is a screw which gears into a toothed wheel I, and communicates the motion to the vertical plate by means of a pulley-wheel (in the same casting with the toothed wheel), and a cord K kept in tension by weights at each end. The carriage on which the vertical plate is mounted can be attached to any convenient point of the cord.

The transits of the artificial sun, or moon and stars can thus be observed with the transit-circle under practically the same conditions as the real objects. At the same time, the true times of transit over the wires are registered automatically on a chronograph by means of the contacts between two sets of platinum studs, one set (a', b', c', d', e', f') corresponding to the artificial objects and carried with the plate, the other set (n, o, p, q, r, s, t, u, v, w, x, y, z) fixed and corresponding to the wires of the transit-circle. [In the diagram q, r, s, u, v, w are omitted to avoid confusion.] The platinum studs are carefully rounded at the parts where contact is made (so that the contact surfaces are hemispheres) and are let into the ends of small brass screws,

which are tapped through insulated narrow brass plates L, M, having thin plates of ebonite (with holes through which the studs project very slightly) on their under and upper surfaces respectively. The studs can thus be readily adjusted vertically to give good contact without interfering with the smooth motion of the vertical plate. For the adjustment of the instants of contact to the times of true transit over the wires, the right ascension micrometer of the transit-circle is used to move the wires so that they respectively bisect the artificial object when it is brought (by slowly turning the spindle of the screw which actuates the pulley wheel) into the respective positions for which contact is made by its stud with each of the studs corresponding to the wires. The readings of the R.A. micrometer are taken for the bisection of the artificial star by each wire, and the micrometer is set to the mean of the readings. A reversion-prism eyepiece is used in these adjustments to eliminate any personality in bisection of a stationary object. Thus the mean of the true times of transit over the wires is adjusted to agree precisely with the mean of the instants of contact with the corresponding studs.

In observations of limbs I propose to use an artificial star as a point of reference, measuring the distance between the artificial limb and star on the plate with a micrometer microscope, and also in the field of view of the transit-circle with the R.A. micrometer. The scale would be given by measuring the distance between two stars on the plate and in the field of the transit-circle. In this way personality in the bisection of a stationary limb would be determined, and the personality in observations of a first or second limb would be found by means of transits. It may be remarked that the reversion-prism eyepiece gives facilities for converting the preceding or following limb (*a* or *b*) into an upper or lower limb, so that personality in N.P.D. observations of limbs can be thus determined.

Plates with apertures representing the various planets may be substituted for any of the four *b*, *c*, *d*, *e*.

Royal Observatory, Greenwich:
1887, *November* 19.

Results obtained with the Personal Equation Machine at the Royal Observatory, Greenwich. By H. H. Turner, M.A., B.Sc.

A full description of the Personal Equation Machine is given by the Astronomer Royal in the preceding paper. Observations were made with this instrument in 1885 and 1886, but, owing to pressure of other work, little more was done than was necessary to test the general practicability of the measures. A series of transits of an artificial star was observed by several observers, the apparent rate of motion being a little greater than that of an equatorial star, and alternately towards

the left (*l*), and towards the right (*r*). This reversal of apparent direction of motion can be obtained either by reversing the actual motion of the plate or by using the reversion-prism eyepiece with the transit-circle; and to eliminate certain errors, both methods were employed in combination. The letters *l* (towards the left of the observer) and *r* (towards the right) are always used to designate the resulting apparent direction of motion, the actual motion of the plate being defined by the letters E (towards the east) and W (towards the west). With the ordinary eyepiece the apparent motion is towards the left when the plate moves towards the east.

The transits were registered automatically on the chronograph which is used for ordinary star observation, the electromagnet usually connected with the clock being temporarily placed in the circuit connected with the instrumental studs. The record made by the observer was made exactly in the same manner as that for the transit of a star, except that the instrument was in a horizontal position and the observer standing erect, which only occurs approximately in the case of stars near the horizon.

The following are the results obtained for absolute personal equation, the sign + signifying that the observer is late in his record. The relative personal equation in use for all objects without distinction, and referred to Mr. Downing as standard observer, is placed in brackets after each observer's name for comparison. The initials H.T., C., A.D., T., L., H., S.D. and R., are those of Mr. Turner, Mr. Criswick, Mr. Downing, Mr. Thackeray, Mr. Lewis, Mr. Hollis, Mr. Dolman, and Mr. Robinson respectively.

Each printed number is the mean of a transit of nine wires.

Observer, H. T. (− 0ˢ·15.)

	Apparent Motion *l*.		Apparent Motion *r*.	
	E.	W.	E.	W.
	s	s	s	s
1885, Aug. 26	+0·07			+0·03
	+0·10			+0·04
	+0·31			+0·03
	+0·26			+0·11
	+0·09			+0·08
1886, May 9	+0·01	−0·02	−0·06	+0·14
	−0·02	+0·03	−0·01	+0·04
May 10	−0·04	−0·04	+0·01	−0·05
27	−0·06	−0·09	−0·09	−0·10
	+0·03	−0·16	−0·15	−0·12
Mean	+0·075	−0·056	−0·060	+0·020
Mean, excluding 1885, Aug. 26	−0·016	−0·056	−0·060	−0·018

Observer C. (+0ˢ·28.)

	Apparent Motion *l.* E.	Apparent Motion *l.* W.	Apparent Motion *r.* E.	Apparent Motion *r.* W.
	s	s	s	s
1885, Aug. 26	+0·45			+0·35
	0·28			0·35
	0·34			0·28
	0·34			0·42
	0·34			0·26
1886, May 18	0·27	+0·22		0·14
	0·31	+0·22		+0·19
	0·25			
	+0·28			
Mean	+0·318	+0·220		+0·284
Mean, excluding 1885, Aug. 26	+0·278	+0·220		+0·165

Observer, A. D. (0ˢ·00.)

1886, May 10	+0·12	+0·07	+0·14	+0·09
	+0·09		+0·06	+0·09
May 27	+0·20	+0·15	+0·20	+0·15
	+0·18	+0·18	+0·10	+0·15
Mean	+0·148	+0·140	+0·125	+0·120

Observer T. (−0ˢ·13.)

1885, Aug.	+0·12			+0·11
	0·07			0·14
	+0·08			+0·13
1886, May 27	−0·07	−0·10	+0·03	−0·08
	−0·09	+0·01	+0·07	−0·11
Mean	+0·030	−0·045	+0·070	+0·038
Mean, excluding 1885, Aug. 26	−0·060	−0·045	+0·070	−0·095

Observer, L. (−0ˢ·01.)

1886, May 18	+0·15	+0·15	+0·13	+0·18
	+0·11	+0·16	+0·16	+0·13
May 27	+0·09	+0·02	+0·01	+0·16
		+0·03	+0·09	
		+0·09	+0·11	
Mean	+0·117	+0·090	+0·100	+0·157

Observer, H. (+0ˢ·23.)

	Apparent Motion *l.* E.	Apparent Motion *l.* W.	Apparent Motion *r.* E.	Apparent Motion *r.* W.
	s	s	s	s
1885, Aug. 26	+0·41			+0·39
	0·38			0·36
	0·37			0·39
	0·41			0·42
	0·36			0 39
1886, May 18	+0·49	+0 54	+0 41	0·51
				+0·47
May 27	+0·36	+0·19	+0·21	+0·40
	+0·28	+0·20	+0·22	+0·32
Means	+0·383	+0·310	+0·280	+0·406
Means, excluding 1885, Aug. 26	+0·377	+0·310	+0·280	+0·425

Observer, S. D. (−0·16.)

1885, Aug. 26	+0·17			+0·44
	+0·15			0·19
	+0·32			0·10
	+0·01			0·18
	+0·13			+0·09
Mean	+0·156			+0·200

Observer, R. (+0·03).

1886, May 9	+0·07	+0·26	+0·21	+0·19
	+0·03	+0·24	+0·19	+0·21
Mean	+0·050	+0 250	+0·200	+0·200

The results for 1885, August 26, have been separated from the others in the second set of means for each observer, because the reversion-prism eyepiece was not used on that day, and also because the general working of the instrument on this first occasion was not quite so satisfactory.

After these preliminary measures some time was spent in making better general arrangements before any detailed investigation was undertaken. Among other things it was considered advisable to use a different form of chronograph. With the one used for the above observations and for ordinary star work, a record consists of a single puncture only, made on drawing-paper by a sharp pricker, there being no sensible difference between an almost instantaneous tap and one where the contact is continued for a considerable fraction of a second;

but it was felt to be desirable in the present instance to have a record of both the make and break of a contact. Accordingly a small chronograph, by Krille, which had been used for mechanical registration was adapted to electrical registration. The records are made by two pens which mark continuous lines round the barrel, except when drawn aside (one to the right and the other to the left) by the electro-magnets. It is found most convenient for reading off the transits to adjust the pens both to the same continuous line, placing one slightly in advance of the other. The distance between them affects every measure, and must therefore be very carefully observed. But by reversing the attachment of the electro-magnets, and placing that which was previously in the observing circuit now in the machine circuit, this distance between the pens enters into the observed measure of personal equation with the opposite sign; and this reversal which is performed by the observer in the middle of his observations on any day, thus eliminates any error in estimation of the distance.

Towards the end of June of the present year a systematic series of observations was undertaken by the four regular transit-circle observers for the determination of the change of personal equation with apparent rate of motion. The method of conducting the observations was as follows:—

A suitable artificial star on the brass plate having been selected, the corresponding stud is brought up from the west into contact with the stud corresponding to the first wire of the transit-circle by an assistant at the instrument, who turns the spindle of the driving-screw very slowly until the click of the electro-magnet on the chronograph is heard. This operation is generally repeated very carefully after the first click has indicated the approximate position for contact. When a satisfactory contact has been obtained, word is given to the observer at the transit-circle, who then bisects the artificial star with the first wire by means of the R.A. micrometer-screw, and records the reading. Two bisections are considered sufficient. The assistant at the instrument is then directed to pass to the second wire, at which the process is repeated, the stud being now bisected with the second wire of the transit-circle so that the reading of the R.A. micrometer is nearly the same. It would be exactly the same as the former if the interval between the portions of the two wire-studs with which the star-stud came in contact were the exact equivalent of the interval between the wires in the transit-circle. Observation shows that the wire-studs have been so well adjusted to these equivalent intervals that a condition to be presently mentioned is fulfilled. The above process is repeated for all the nine wires, and the mean of the 18 nearly equal readings (2 for each wire) of the R.A. micrometer is then taken. If now the micrometer be set to this mean reading, which for the moment we will suppose to apply accurately to each of the 9 wires, and the plate carrying the artificial star and its stud be

set in motion from west to east, an observer with zero personal equation would record the transit of the star at each wire exactly at the same instant at which contact is made by the star-stud with the corresponding wire-stud, and the pens in the instrumental and observing circuits would be deflected simultaneously. If the pen in the observing circuit is deflected later than the other, the observer is considered to have a positive personal equation. The condition referred to above is that the bisection and contact should be for every wire very nearly simultaneous; otherwise the records of the observer and machine would be made at sensibly different points of the star's path, and it is possible that this might introduce small errors.

Before, however, any transits are observed in this way, the above process of "taking adjustments," as it has been called, is repeated for the other side of the studs; that is to say, the star-stud is brought up from the east, so that the artificial star moves towards the west and appears to the observer to move towards his right. Another set of eighteen similar readings of the R.A. micrometer is thus obtained, the mean of which can be used in exactly the same way for setting the micrometer so that with reversed motion the ideal observer would record simultaneously with the machine. As a general rule, throughout the whole series of observations, the transits and adjustments were made in corresponding pairs with motion E and motion W.

After the observations for "adjustment" a number of transits —generally about a dozen with each direction of motion—were taken, the rate of motion being changed after every pair. This rate is controlled by the position of the brass disc on its spindle; and the spindle is graduated in twentieths of an inch to the right and left of a zero which corresponds to zero rate of motion. It was found by preliminary experiments that if the brass disc be set to the reading $22^{d}{\cdot}0$, the apparent rate of motion of the artificial star is the same as that of an equatorial star, and accordingly the following settings of the spindle were selected for trial: $33^{d}{\cdot}0$, $22^{d}{\cdot}0$, $16^{d}{\cdot}0$, $11^{d}{\cdot}0$, $6^{d}{\cdot}0$, $3^{d}\,0$. The first of these corresponds to a rate half as large again as that of an equatorial star, while the remaining settings correspond to the rates of motion of stars at N.P.D. 90°, $43\frac{1}{2}°$, 30°, 15°, and 9° respectively. The last of these readings was after a few trials discarded as inconveniently slow for use in the present investigation. The succession of readings on any day was selected arbitrarily, so as to avoid any possible influence of systematic change of rate. Between separate transits, while the disc was being carefully set on the spindle by the assistant at the instrument, the observer recorded several consecutive seconds on the chronograph to indicate the time value of the chronograph scale on the particular day. This was necessary because the chronograph was somewhat exposed to the wind, and controlled merely by a fan governor; and it was found impossible to avoid small changes of rate. The mean of all the scale values thus indicated on any day has generally been adopted for

the reduction of the observations on that day, but sometimes, where it is clear that the chronograph has changed its rate during the observations, the observations on that day have been separated into groups. In any case the influence of slight changes of rate in the chronograph on the result obtained is very small.

The clock used to give the second signals was the transit clock, Hardy, which stands directly behind the observer and ticks loudly. The observer can thus without much trouble note the whole time of transit of the star to the nearest second, and since 1887, Sept. 8, this has been made the practice. Information was thus accumulated, first, as to the accuracy of the correspondence between the spindle setting $22^{d}{\cdot}0$ and equatorial rate; and secondly, as to the legitimacy of the assumption that the rate at which the brass disc was driven varied directly as the distance from the centre of the circular plate. In both cases the result was satisfactory [see note (5) at the end of the paper].

After a number of transits had been observed, the 'adjustments' were repeated exactly in the same order as at first, and the set of observations was complete. The process of reading off the differences in time recorded by the observer and by the machine, and of reducing the observations, is so simple as not to require further explanation; and we may give at once the concluded results for absolute personal equation, arranged with the spindle setting as argument.

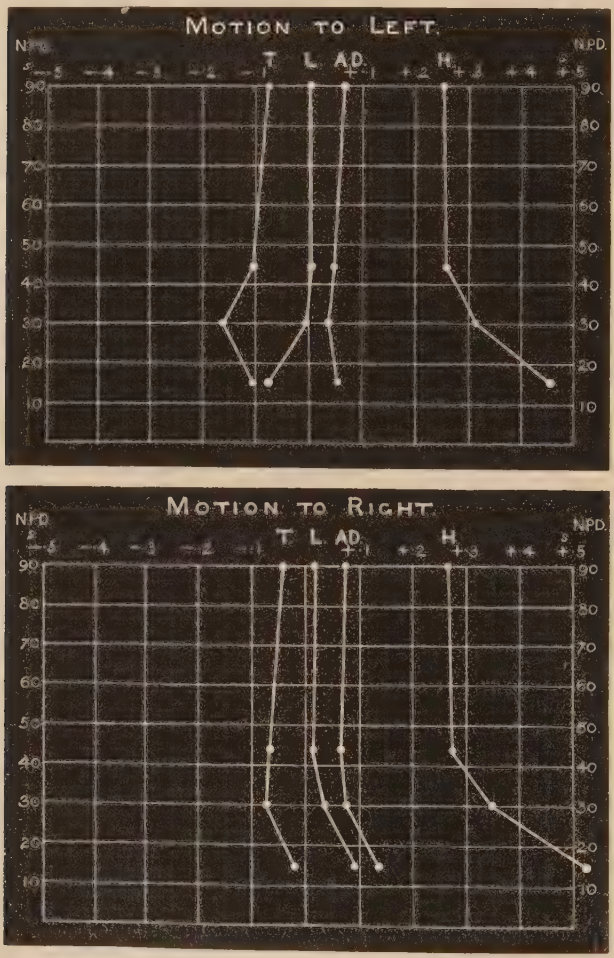
The probable error of a complete transit is found from the residuals to be $0^{s}{\cdot}030$, $0^{s}{\cdot}035$, $0^{s}{\cdot}044$, $0^{s}{\cdot}056$, $0^{s}{\cdot}093$ at the various spindle settings respectively; and from these numbers the probable errors given in the table have been deduced.

The number of transits observed in each case is given in brackets.

Absolute Personal Equation at Spindle Settings.

Obsr.	Direction of Motion.	33d		22d Equatorial Rate.		16d Rate at N.P.D. 43½°.		11d Rate at N.P.D. 30°.		6d Rate at N.P.D. 15°.	
		s	s	s	s	s	s	s	s	s	s
H. T.	*l*	−0·053	±0·013 (6)	−0·065	±0·015 (6)	−0·098	±0·020 (5)	−0·115	±0·028 (4)		
		-0·063	±0·013 (6)	−0·043	±0·015 (7)	−0·048	±0·020 (5)	−0·045	±0·028 (4)		
A. D.	*l*	+0·094	±0·007 (18)	+0·064	±0·008 (19)	+0·045	±0·011 (15)	+0·036	±0·014 (15)	+0·052	±0·026 (13)
	r	+0·072	±0·007 (17)	+0·075	±0·008 (19)	+0·065	±0·011 (15)	+0·076	±0·015 (14)	+0·137	±0·026 (13)
T.	*l*	−0·042	±0·006 (26)	−0·077	±0·007 (25)	−0·108	±0·009 (22)	−0·158	±0·014 (17)	−0·109	±0·024 (15)
	r	−0·044	±0·006 (26)	−0·036	±0·007 (25)	−0·062	±0·009 (22)	−0·069	±0·014 (18)	−0·019	±0·024 (15)
L.	*l*	+0·020	±0·006 (25)	+0·003	±0·007 (22)	+0·003	±0·010 (20)	−0·008	±0·012 (21)	−0·077	±0·022 (18)
	r	+0·013	±0·006 (24)	+0·021	±0·008 (20)	+0·014	±0·010 (20)	+0·036	±0·013 (20)	+0·093	±0·022 (17)
H.	*l*	+0·221	±0·007 (18)	+0·256	±0·007 (23)	+0·260	±0·012 (14)	+0·316	±0·013 (19)	+0·457	±0·023 (16)
	r	+0·234	±0·007 (19)	+0·267	±0·007 (23)	+0·274	±0·012 (14)	+0·349	±0·013 (19)	+0·528	±0·024 (15)

The following diagrams exhibit these results graphically for the four regular observers, and for rates of motion which occur in actual star observing. The whole width of each diagram represents a second of time, and the curve corresponding to each observer is to the right or left of the centre according as he is late or early in his record. The rate of motion is indicated by the corresponding N.P.D. for a real star.



The probable errors for a single transit do not increase directly as the rate of motion decreases; on reducing them to the equator the series of numbers becomes

0ˢ·045 0ˢ·035 0ˢ·032 0ˢ·028 0ˢ·025.

so that the observations at slower rates are more accurate. These "reduced" probable errors are represented very accurately by the formula

$$\text{Prob. error} = 0^{s}\cdot022 + 0^{s}\cdot0132 \times \frac{\text{spindle-setting}}{22},$$

so that the actual probable error is

$$0^{s}\cdot022 \times \frac{22}{\text{spindle-setting}} + 0^{s}\cdot0132.$$

Of these two quantities the first is a constant error in *arc*, and the second in time. The first probably represents the error of bisection of the star's image, and the second the error the observer is liable to make in trying to tap at a definite instant.

The probable error of the transit of an equatorial star observed over nine wires as found by Mr. Dunkin (*Monthly Notices*, vol. xxiv.) is $0^{s}\cdot017$; and the probable error of a result for right ascension is $0^{s}\cdot034$, the difference being due to errors in the determinations of the position of the transit-circle.

The determinations of personal equation above tabulated are fairly comparable with the second kind of measure; for here also various instrumental errors of adjustment are added to those of simple errors in transit observing. It is satisfactory to find such a close agreement between the deduced probable errors for a complete transit in the two cases.

The results for personal equation are checked at various points by other investigations:

A. The *relative* personal equations for clock-stars are investigated annually in the "Greenwich Observations." The standard observer is A. D. Till recently the direction of motion was always *l*, but the reversion-prism eyepiece has been used since 1884 June, for the observation of two clock-stars with apparent motion *r* on every fine night. The great majority of clock-stars are however still observed with the ordinary eyepiece, i.e. with apparent motion *l*, and the mean rate is a little less than equatorial—corresponding to a spindle setting of about 21^{d} instead of 22^{d}.

Selecting then the proper numbers from the above results for comparison with the relative personal equations we get

Obs.	Absolute P.E.	P.E. relative to A. D.	Difference = A. D.'s abs. P. E.
	s s	s	s
H. T.	$-0\,07 \pm 0\cdot015$	$-0\cdot15$	$+0\cdot08$
A. D.	$+0\cdot06 \pm 0\cdot008$	...	$+0\cdot06$
T.	$-0\cdot08 \pm 0\cdot007$	$-0\cdot13$	$+0\cdot05$
L.	$+0\cdot00 \pm 0\cdot007$	$-0\cdot01$	$+0\cdot01$
H.	$+0\cdot26 \pm 0\cdot007$	$+0\cdot23$	$+0\cdot03$
		Mean	$+0\cdot05$

The small discrepancies in the quantity found in the last column are quite consistent with a probable error of about $0^{s}\cdot010$ in each of the quantities between which it is the difference.

B. Besides these relative personal equations between different observers we have for comparison two sets of independently determined differences between the personal equations for the same observer with motion l and motion r respectively. The first set is deduced from comparison of clock errors obtained from observations with the transit-circle using the reversion-prism eyepiece.

Extracting in the same way the required differences $(r-l)$ from the table, for spindle reading 21^{d} we get

	From Machine results.	From Star results.	No. of Determinations.
	s s	s s	
H. T.	$+0\cdot027\pm0\cdot020$	$-0\cdot035\pm0\cdot011$	12
A. D.	$+0\cdot014\pm0\cdot012$	$+0\cdot010\pm0\cdot004$	70
T.	$+0\,042\pm0\cdot010$	$+0\cdot063\pm0\cdot012$	28
L.	$+0\cdot017\pm0\cdot011$	$+0\cdot020\pm0\cdot004$	72
H.	$+0\cdot011\pm0\,011$	$+0\cdot010\pm0\cdot004$	85

The number of determinations given in the last column indicates the number of nights on which clock-stars were observed with the reversion-prism. Usually two were observed on each night, but the transits were generally over four wires only. The probable errors are deduced from the residuals of the results for each night.

The second set of measures of the same quantity for stars moving rather more slowly was made with the altazimuth, the same star being observed at practically the same transit with both directions of apparent motion.

Taking out the differences for spindle reading 16^{d} as most suitable for comparison, we have for differences $(r-l)$:

	From Machine results.	From Altaz. results.
	s s	s s
H. T.	$+0\,050\pm0\cdot022$	$+0\,041\pm0\,020$
A. D.	$+0\cdot020\pm0\cdot011$	$+0\cdot030\pm0\cdot012$
T.	$+0\,046\pm0\cdot010$	$+0\cdot039\pm0\cdot017$
L.	$+0\cdot011\pm0\cdot010$	$+0\cdot047\pm0\cdot013$
H.	$+0\cdot014\pm0\cdot011$	$-0\cdot015\pm0\cdot009$

The agreement may be therefore considered satisfactory.

Returning to the consideration of the table of absolute personal equations, the chief point to be considered is the effect these small differences, hitherto neglected, would have on the Greenwich right ascensions. As regards clock-stars, whose rate of motion varies from that corresponding to spindle setting $22^{d}\cdot0$ (equatorial) to $17^{d}\cdot3$ (α *Lyræ*), it appears that two of the regular observers, L. and H., do not vary in habit between these limits, but that the

other two change nearly $0^{s}\cdot02$ and $0^{s}\cdot03$ in the same direction, so that the mean of the four observers would give correct results within $0^{s}\cdot01$ for the whole range.

As regards the stars catalogued, some of which move slowly and some have reversed direction of motion, the average effect is not quite insensible, the mean personal equation for the four observers being as below :—

N.P.D.		90°	43½°	30°	15°
Motion	*l*	+0·062	+0·050	+0 047	+0·081
„	*r*	+0·082	+0·073	+0 098	+0·185

There does not appear to be any general law representing the change of personal equation with rate. We might suppose the personal equation to be made up partly of error of bisection and partly of a constant error in time, either deliberate or unconscious. We should expect the latter not to vary with the rate or direction of motion, and the former to vary inversely as the rate and to change sign with the direction of motion. This is fulfilled approximately for all the observers except H., whose "error of bisection" amounting to nearly $1''\cdot0$ does not change sign with the direction of motion; so that in this case the observer apparently waits until the star has travelled about $1''$ past the wire—whatever be the direction of motion—and then "hangs fire" for about $0^{s}\cdot2$ before the record is complete. Such a well-marked exception rather precludes generalisation.

The quantities to be measured are all so small that their determination is originally liable to several sources of systematic error. The following notes on some special points may be of interest :—

(1) *Systematic error in reading off the transits.*—With the exception of two occasions, on which the observer read off his own transits, the differences were all read off by Mr. Downing. Any systematic error would then be presumably common to the whole series. But the precaution adopted of interchanging the circuits in the middle of the observations almost certainly eliminates any error of this kind. For instance, if Mr. Downing reads off every distance on the chronograph too large by $0^{d}\cdot01$ of the scale (each of the ink lines defining this distance is several times this quantity), the first group of deduced personal equations would be all too large by $-\frac{0^{s}\cdot007}{S}$, where S is the ratio of the spindle setting to $22^{d}\cdot0$; but the second group would be all too small by the same quantity, and hence this error is practically eliminated in the mean result for each day.

(2) *The error in measurement of the distance between the pens* has been already referred to, and is eliminated in the same manner as in (1).

(3) *Permanence of the positions for contact between the studs.*—This is one of the most vitally important points in the working of the instrument, and one of the most satisfactory. The studs

are cylinders carefully rounded at the ends, so that the contact surfaces are approximately hemispheres. The upper stud is lowered until it will touch one of the lower set when about $0^{in}\cdot01$ (corresponding to about $3''$) to the left or right of it; and consequently remains in contact with it for about $0^{in}\cdot02$ as it is carried over it. There is accordingly a slight lifting of the plate carrying the artificial star whenever one of the studs attached to it passes over one of the fixed studs; but so long as the above approximation of the studs is not exceeded, no appreciable interruption to the smoothness of the transit is discernible. Had this been the case, the difficulty could have been got over by giving the star-stud a small freedom of motion in a vertical direction relatively to the plate, the attachment being made by means of a spring instead of being rigid. But no such arrangement is found necessary, for the jerkiness in transit, noticeable when the duration of contact is large, disappears when it is adjusted as above to a total length of about $0^{in}\cdot02$ (corresponding to about $6''$) in the transit-circle telescope; or, in other words, when the difference of readings of the R.A. micrometer for bisection of the artificial star when its stud is brought into contact from the left and right respectively is about $0^{r}\cdot400$. The mean value of this quantity found from all the observations is $0^{r}\cdot470$. On the other hand, if the length of contact is initially adjusted to much less than this, the contact is liable to fail after a number of transits owing to a little rubbing down of the points, or slight strain, or possibly some electrical action at the points of contact. Such changes are detected by measurements of the length of contact registered in transit, and by comparison of the adjustments taken after the transits with those taken before; and the position of a single stud for contact is rarely found to vary as much as $0^{in}\cdot005$ (corresponding to $1''\cdot5$). In preliminary experiments with the machine the changes had been somewhat larger and much more irregular, but from experiments made by Mr. Lewis, June 10–22, a large part of the disturbance was traced to the Sun's heat when sunlight was used to illuminate the star, the Sun's rays having also fallen on the studs, no doubt causing irregular expansion. On taking care to screen these portions of the instrument, the changes were immediately reduced in magnitude, and part of the apparent irregularity still remaining is no doubt error of observation. It is found, however, that the mean effect is a slight shortening of the contacts, the action being evenly distributed at the two ends, as might be expected from the symmetrical arrangement. The mean of this "wear" on the 32 days of observation is $0''\cdot33$ on the right and $0''\cdot36$ on the left, or a total shortening of $0''\cdot69 = 0^{in}\cdot0023$ in the whole length of a contact. On one day only was the mean wear for the 9 studs so much as $1''\cdot5 = 0^{in}\cdot005$, and on many days it was insensible.

Since the R.A. micrometer is set throughout the transits to readings determined by the first set of adjustments, the effect of

this receding of the contacts, which a discussion of the lengths of contact registered in transit shows to be gradual, is to attribute to the observer a gradually increasing personal equation, and a small correction becomes requisite. Where the total change is so small, however, it was considered sufficient to correct the transits as though the true position for contact were throughout the mean of those indicated by the two sets of adjustments.

(4) The distance between positions for contact on the right and left, i.e. the length of contact, is also registered on the chronograph. It is interesting to compare the value of this length as recorded by the deflection of the chronograph pen when the stud is in continuous motion with the value obtained by means of the R.A. micrometer in the position of rest. Special observations were taken with this object on June 22 and June 27, and the observations made on several subsequent days have been also discussed.

The following table shows the mean value of the length of a contact for one stud, as shown by the "adjustments" (in second column) and from registers on the chronograph for both directions of motion in the next column:—

Date.	Adjustments.	Transits.
	″	″
June 22	5·81	5·65
27	6·22	5·70
July 18	5·99	5·47
21	4·86	4·98
Aug. 1	4·82	5·58
Sept. 8	2·90	4·64
9	6·25	6·47
Mean	5·26	5·70

The small difference thus indicated is readily explicable on the assumption of a very slight sticking together of the studs for a small period longer than consistent with absolutely uniform motion. It was expected that such a sticking would have a constant time-value, and thus affect the more rapid rates of motion relatively to the slower. The observations on available days were accordingly collected under the various rates of motion with the following result:—

Spindle Setting.	Length of Contact.
d	″
33	5·36
22	5·42
16	5·58
11	5·50
6	5·30
Adjustments	4·96

There is thus no great difference between the duration of contact for slow and quick rates.

Part of this small discrepancy between measures at rest and in motion is possibly due to systematic error in reading off the chronograph intervals.

(5) The correspondence of the spindle setting $22^{d}\cdot0$ to equatorial rate has been carefully tested. On the earlier days one of the intervals between the wires of a transit was read from the chronograph. The equatorial value of this interval is $2^{s}\cdot811$. The mean value of this interval in time for the various rates of motion is as follows:—

d	d	d	d	d	d
33·0	22·0	16·0	11·0	6·0	3·0
s	s	s	s	s	s
1·801	2·753	3·691	5·404	9·913	20·650

or, reduced to the corresponding value at reading $22^{d}\cdot0$,

s	s	s	s	s	s
2·702	2·753	2·684	2·702	2·704	2·816

To obtain the second line it is assumed that the rate varies inversely as the spindle setting.

It was found, however, that, owing to the variations in rate of the chronograph, this was not a satisfactory method of measuring the rate of transit. The individual observations show large discrepancies, which would amply explain the above small differences in the means. The practice mentioned above was subsequently adopted of observing the whole time of transit to the nearest second. The mean results are as follows:—

Spindle setting	d 33	d 22	d 16	d 11	d 6
	s	s	s	s	s
Motion *l* ...	19·08	27·81	37·93	54·02	96·88
Motion *r* ...	18·81	27·91	37·92	54·36	100·09

or, reducing to reading $22^{d}\cdot0$,

	s	s	s	s	s
l	28·62	27·81	27·69	27·01	26·15
r	28·22	27·91	27·68	27·18	27·02

The equatorial interval of the transit wires being $27^{s}\cdot642$, the correspondence of the setting 22^{d} to equatorial rate may be considered satisfactory.

Note on the Probable Errors of the Star Places of the Argentine General Catalogue for 1875, *and the Cape Catalogue for* 1880. By A. M. W. Downing, M.A.

As a supplement to my paper on the star places of the Argentine General Catalogue for 1875, and the Cape Catalogue for 1880, printed in the *Monthly Notices* for last June, the following values of the probable errors of a difference of the catalogue places at different N.P.D.s. may be of interest. In the calculation of these probable errors it has not been thought necessary to make use of all the available material, but only of that resulting from the comparison of the places of stars of R.A. 0^h–1^h, 6^h–7^h, 12^h–13^h, and 18^h–19^h.

The following table gives the results of the computation :—

N.P.D.	No. of Stars.	Probable Error of a Single $\Delta\alpha$	Probable Error of a Single $\Delta\alpha \sin$ N.P.D.	Probable Error of a Single $\Delta\delta$
° °		s	s	″
90–100	38	±0·050		±0″·76
100–110	36	±0·064		±0·62
110–115	91	±0·048	±0·052	±0·57
115–120	194	±0·054		±0·51
120–125	207	±0·059		±0·56
125–130	194	±0·068		±0·56
130–135	200	±0·065	±0·051	±0·54
135–140	181	±0·074		±0·46
140–145	194	±0·089		±0·47
145–150	178	±0·084	±0·047	±0·50
150–155	133	±0·088		±0·48
155–160	93	±0·111	±0·041	±0·55
160–165	84	±0·127		±0·71
165–170	63	±0·201	±0·043	±0·52
170–180	47	±0·291	±0·025	±0·62

The mean value of the probable error of a single $\Delta\alpha \sin$ N.P.D. is $\pm 0^s{\cdot}047$; and, assuming that the star places in the two catalogues are equally free from accidental errors, we find that the probable error of a R.A. in either $= \pm 0^s{\cdot}033$ expressed in equatorial time. The mean value of the probable error of a single $\Delta\delta$ is $\pm 0''{\cdot}55$; and, on the same assumption, it follows that the probable error of a N.P.D. in either catalogue $= \pm 0''{\cdot}39$. It appears, however, from Herr Backlund's investigations (*V. J. S.* 20 Jahrgang, III. Heft) that the probable errors of a single Cape observation in R.A. and N.P.D. are $\pm 0^s{\cdot}046$ cosec N.P.D. and $\pm 0''{\cdot}61$ respectively, and as each place in the Cape Catalogue depends, on the average, on 3 observations, we have the probable

error of a R.A. in the Cape Catalogue $= \pm 0^s{\cdot}027$ cosec N.P.D., and the probable error of a N.P.D. $= \pm 0''{\cdot}35$. Combining these values with the probable errors of a single $\Delta\alpha$ sin N.P.D. and a single $\Delta\delta$ given above, it appears that the probable errors of a R.A. and N.P.D. of the Argentine General Catalogue are $\pm 0^s{\cdot}038$ cosec N.P.D. and $\pm 0''{\cdot}42$ respectively.

On the Reduction of Star Places by Bohnenberger's Method.

By Professor Truman Henry Safford.

Every astronomer who has had much to do with the reduction of star places from one epoch to another is aware that in case the star be very near the pole, or the epochs very distant, the method invented by Bohnenberger must replace the ordinary employment of annual precessions and secular variations.

It is easy enough to see that when the product of the interval by the tangent of the star's declination reaches a certain amount the precession series is no longer convergent. If I can rely upon my remembrance of a mathematical investigation found in many text-books, the series

$$1-\tfrac{1}{3}+\tfrac{1}{5}-\tfrac{1}{7}+\tfrac{1}{9}-\tfrac{1}{11}, \text{ etc. for } \tfrac{1}{4}\pi = {\cdot}78539\ldots$$

is just on the line between convergence and non-convergence; and when the series, by which the right ascension of a star is expressed in terms of the time, contains as a part of itself a series of this degree of convergence it is no longer practicable to use it.

From Bessel's investigation on pages x and xi of the introduction to the *Tabulæ Regiomontanæ*, one can readily enough see that a star's right ascension as a function of the time contains terms of the form

$$\begin{aligned} & tn \tan\delta \sin\alpha \\ & + \frac{t^2n^2}{2}\tan^2\delta \sin 2\alpha \\ & + \frac{t^3n^3}{3}\tan^3\delta \sin 3\alpha \\ & + \frac{t^4n^4}{4}\tan^4\delta \sin 4\alpha. \\ & + \&c. \end{aligned}$$

together with other terms multiplied by the same powers of $\tan\delta$, but lower power of the time. The terms here given are those which determine the convergence when $\tan\delta$ is very great.

If, now, $tn \tan\delta = 1$ we shall have a series which exhibits precisely the same kind of lack of convergence as the well-known numerical arc which I quoted before.

As n is roughly $20''$ or $\frac{1}{10000}$ of radius, it is plain that this

absolute failure of convergence takes place when $t \tan \delta$ is about 10,000; or for a star 1° from the pole is about 180 years.

Using similar considerations I have been in the habit of selecting the epochs for the use of Bohnenberger's formula as follows.

We have tables for the secular variation, and for the term multiplied by the third power of the time. While these tables are not quite complete enough for close polar stars they are a very great help in checking calculations, and it is easy enough to use them or to calculate the terms depending upon the third, and by their variations from year to year those depending upon the fourth power of the time. So that when the term

$$\frac{t^5 n^5}{5} \tan^5 \delta \sin 5\alpha$$

is insensible, it is not necessarry to employ the trigonometrical formula.

But it will be safer not to consider the sine of five times the right ascension as a factor; as, when it is casually small, the next factor sin 6α may be large; and we may require

$$\frac{(tn \tan \delta)^5}{5}$$

as the quantity to be made 0″·01 of arc. We shall then have

$$\frac{tn \tan \delta}{206264''{\cdot}8} = \sqrt[5]{\frac{0''{\cdot}05}{206264''{\cdot}8}},$$

or

$$5 \log \frac{tn \tan \delta}{206264''{\cdot}8} = 3{\cdot}38455 - 10,$$

or

$$\log \frac{tn \tan \delta}{206264''{\cdot}8} = 8{\cdot}67691 - 10,$$

or

$$\log tn \tan \delta = 3{\cdot}99134.$$

Taking $\log n$ for 1900, according to Struve = 1·30216, we shall have

$$\log t \tan \delta = 2{\cdot}68918,$$

or

$$t \tan \delta = 488{\cdot}9 \text{ years.}$$

For *Polaris* in 1887, whose declination is 88° 42′·5, the interval here indicated is about 11 years. That is to say, the right ascension of *Polaris* can now be carried forward or back 11 years by the use of the first four differential coefficients of the right ascension with respect to the time; so that a trigonometrical computation for every 20 years is amply sufficient to afford a check at the beginning of one period and the end of the next preceding.

For a star in the declination 88° 58′ the single interval t is rather less than 9 years, and the double rather more than 17; so that to compute a series of places from year to year of λ *Ursæ Minoris* or Groombridge 1119 = B.A.C. 2320 (*Connaissances des Temps*) the trigonometrical computation should be employed every 16 years at least, to make sure of 0″·01 in the right ascension. Similar consideration should be applied to find out when other terms become insensible, or less than 0″·01.

Suppose we employ the general formula

$$\frac{1}{p}\left(tn\tan\delta\right)^{p}=0''\cdot01,$$

making p successively 3, 4, 5 . . . and we shall have

$$t\tan\delta=\left(\frac{p\times0''\cdot01}{206264''\cdot8}\right)^{\frac{1}{p}}\frac{206264''\cdot8}{n},$$

as given in the following little table:—

p	$t\tan\delta$ years.	t for *Polaris*. y	t for λ *Ursæ Minoris*. y
3	54·1	1·2	1·0
4	215·9	4·9	3·9
5	488·9	11·	8·9
6	837·3	19·	15·
7	1225·	28·	22·
8	1625·	37·	30·
9	2021·	46·	37·
10	2403·	54·	44·

The formula is

$$\log t\tan\delta=4\cdot01226-\frac{7\cdot31443}{p}+\frac{\log p}{p}.$$

Practically, anyone who attempts to use the higher terms up to the 10th in reducing star places will find it a very uncertain and perplexing matter, far less easy than the judicious employment of the trigonometrical formulæ.

If in any given case, like that of λ *Ursæ Minoris* for example, it is desired to extend the series to the 5th term, this can be practically accomplished as follows:—

The highest part only in power of $\tan\delta$ of the 4th term will be

$$t^{4}\frac{n'^{4}}{4}\tan^{4}\delta\sin4\alpha,$$

and that of the 5th term

$$t^{5}\frac{n'^{5}}{5}\tan^{5}\delta\sin5\alpha,$$

which last will doubtless be sufficiently approximate to the total

value of the term for 10 years, as it cannot exceed 0″·02 for this period, which is at any rate quite insensible when reduced to the parallel of the star.

If, indeed, we choose to take 0″·01 *after reduction to the parallel* as our limit of accuracy in computation, we may practically employ the t corresponding to a term farther along in the series than we intend to employ; but a skilled computer will soon find the practical limits beyond which these theoretical arcs may be extended without damage.

In this way it will be seen that for stars not very near the pole the terms beyond the ordinary "secular variation" soon become sensible. As a long and valuable memoir by two Austrian astronomers, Herz and Strobl, which I have seen but do not yet possess, relates, in part, to this subject in its application to Auwers's fundamental catalogue, I will only say here that for $\delta = 45°$, t should not be more than 54 years to secure (without examination of the special case) the insensibility to less than 0″·01 of the error caused by omitting the third term. Professor Argelander in fact calculated these values for all declinations over 39°; his greatest interval was 120 years (1755–1875), which agrees well enough with my table.

The actual calculation by Bohnenberger's method requires the use of three quantities $z+\lambda$, $z'-\lambda'$, and θ, which depend partly upon the epoch from which, and that to which, the reduction is effected; and partly upon the epoch taken as the fundamental one for the precession, constants, and so forth.

In the use of Struve's precessions, now entirely general, the fundamental epoch is of course 1800. I have used 1855 as the general date from and to which the places are to be reduced, following Carrington for reasons of convenience. The same date had been also adopted by Dr. Gould, and was afterwards used by Professor Boss; and I have not thought it worth while to change at present to a later epoch. Carrington's catalogue affords (for all close northern polars) approximate positions at once for this year; it also lies between the two Radcliffe catalogues, which can by their own data be readily reduced to it; and is nearly identical with the general mean date (by weight) of the existing catalogues of these northern stars. The method which I employ makes this a convenience, and at the same time renders it needless to select a later date for the constants $z+\lambda$, &c.

If a change is to be made in this respect I think the next year adopted should be 1900, so far as these quantities are concerned. As a matter of curiosity I desired to follow the changes in the place of *Polaris*, and so computed some values of their constants up to 2100. In the table which follows I give them; those to be added to the right ascension are expressed in time. This is now rendered a matter of the greatest convenience by the admirable tables of the previously mentioned astronomer

Norbert Herz,* published by Teubner at Leipzig in 1885; a book which I find indispensable in all computations of precession.

At a future time I intend to publish the results of my discussion of the relative movements of *Polaris* and the north pole; it is enough to say here that the nearest approach takes place, according to my calculation, some time in the year 2102 at a north declination of 89° 32′ 23″; the star will reach 89° about 1944, and be for about 300 years within a degree of the pole.

The tables have been pretty thoroughly checked in various ways. They were computed for every twenty years with seven-figure logarithms (Schrön's), using the additional marks to indicate the half of the seventh decimal, and carrying the interpolations to the eighth figure; and were compared with values given by Dr. Gould and Professor Boss for various dates, and by differences for intermediate years.

Moreover, the position of *Polaris* was brought up to 1900 from 1855, and then to 2000 and 2100 by both tables, with very slightly different results; in neither co-ordinate more than 0″·002 in arc of a great circle. I had no ten-figure table at hand, but it hardly seemed necessary.

The simplest method of discussing a long series of polar-star places collected from the various catalogues is to assume a position for 1855·0 from a careful preliminary discussion; reduce it to the various epochs of Table I. for which there are observations, and compare with observations. The benefit of this process is that defective or erroneous right ascensions do not affect the reductions of the declination; while the error in the assumed place is readily found and allowance made if necessary.

TABLE I.—*For Bohnenberger's Method.*

(The reductions are *from* 1855·0 to the tabular dates.)

Date.	$z+\lambda$	$z'+\lambda'$	θ
	m s	m s	′ ″
1755	−2 33·588	−2 33·506	−33 25·987
1760	2 25·909	2 25·835	31 45·671
1780	1 55·196	1 55·142	25 4·423
1790	1 39·841	1 39·791	21 43·816
1800	1 24·486	1 24·438	18 23·202
1810	1 9·133	1 9·083	15 2·603
1815	1 1·456	1 1·404	13 22·305
1820	0 53·780	0 53·724	11 42·010
1828	0 41·497	0 41·436	9 1·542
1830	0 38·427	0 38·364	8 21·426
1835	0 30·751	0 30·683	6 41·137
1840	0 23·075	0 23·001	5 0·849

* *Siebenstellige Logarithmen der trigonometrischen Functionen für jede Zeitsecunde*, 186 pp. 8vo.

Date.	$z+\lambda$	$z'+\lambda'$	θ
	m s	m s	′ ″
1842	0 20·005	0 19·928	4 20·735
1845	0 15·400	0 15·318	3 20·564
1850	0 7·724	0 7·635	1 40·281
1852	0 4.654	−0 4·562	−1 0·168
1855	−0 0·049	+0 0·049	0·000
1860	+0 7·627	0 7·733	+1 40·279
1864	0 13·766	0 13·881	3 0·500
1865	0 15·301	0 15·418	3 20·555
1870	0 22·976	0 23·104	5 0·830
1872	0 26·046	0 26·178	5 40·939
1875	0 30·651	0 30·790	6 41·102
1880	0 38·325	0 38·477	8 21·372
1885	0 46·000	0 46·165	10 1·640
1890	0 53·674	0 53·853	11 41·905
1900	1 9·022	1 9·232	15 2·428
1920	1 39·715	1 39·997	21 43·445
1940	2 10·407	2 10·772	28 24·422
1960	2 41·096	2 41·558	35 5·355
1980	3 11·782	3 12·354	41 46·244
2000	3 42·467	3 43·161	48 27·085
2020	4 13·149	4 13·978	55 7·879
2040	4 43·829	4 44·807	° 1 1 48·622
2060	5 14·507	5 15·646	1 8 29·312
2080	5 45·182	5 46·496	1 15 9·947
2100	6 15·856	6 17·357	1 21 50·525

TABLE II.—*For Bohnenberger's Method.*

(Reduction from 1900 to tabular date.)

Date.	$z+\lambda$	$z'+\lambda'$	θ
	m s	m s	′ ″
1920	+0 30·532	+0 30·926	+ 6 41·025
1940	1 1·223	1 1·701	13 22·013
1960	1 31·912	1 32·486	20 2·962
1980	2 2·598	2 3·282	26 43·872
2000	2 33·281	2 34·088	33 24·739
2020	3 3·962	3 4·905	40 5·562
2040	3 34·641	3 35·732	47 46·339
2060	4 5·318	4 6·570	53 27·068
2080	4 35·992	4 37·419	° 1 0 7·746
2100	5 6·665	5 8·278	1 6 48·373

The formulæ for reductions from 1855 or 1900 to any tabular date are (here α, δ are the position for the fundamental epoch, α', δ' those for the tabular date).

$$\begin{aligned} A &= \alpha + z + \lambda \\ m \cos M &= \cos \delta \cos A \\ m \sin M &= \sin \delta \\ \cos \delta' \sin A' &= \cos \delta \sin A \\ \cos \delta' \cos A' &= m \cos (M + \theta) \\ \sin \delta' &= m \sin (M + \theta) \\ \alpha' &= A' + z' - \lambda'. \end{aligned}$$

Other formulæ giving the same results are frequently employed, but I find these on the whole the most convenient.

On the Orbit of p Eridani. By J. E. Gore.

In previous investigations on the orbit of this southern binary star it seems to have been assumed that Dunlop's measure in 1825 is probably erroneous, owing to the difficulty experienced in making it fit satisfactorily into an orbit with the other measures. Assuming, however, the approximate correctness of Dunlop's measure, and using some recent measures by Mr. Tebbutt (N.S.W.), and by Mr. Pollock at the Sydney Observatory, I have computed the following provisional elements :—

Elements of p Eridani.

$P = 302{\cdot}37$ years.	$\Omega = 135°\ 0'$ (1870·0).
$T = 1823{\cdot}55$.	$\lambda = 240°\ 0'$.
$e = 0{\cdot}674$.	$a = 6''{\cdot}96$.
$\gamma = 38°\ 31'$.	$\mu = -1°{\cdot}19$.

The following is a comparison between the recorded measures and the positions computed from the above elements. The computed position-angles have been corrected for the effect of precession to 1870·0.

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	″
1825·96	Dunlop	343·1	348·6	−5·5	2·5 (est)	2·12	+0·38 ±
1835·00	Sir J. Herschel	302·3	303·9	−1·6	3·65	3·17	+0·48
1845·88	Jacob	276·0	276·7	−0·7	4·16	4·13	+0·03
1846·35	,,	276·5	275·8	+0·7	4·32	4·18	+0·14
1849·82	,,	270·0	269·5	+0·5	...	...	...
1850·80	,,	268·7	267·9	+0·8	...	4·51	...
1851·79	,,	266·4	266·3	+0·1	4·30	4·59	−0·29

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1852·76	Jacob	264°·8	264°·8	0°·0	4″·14	4″·66	−0″·52
1853·96	Powell	263·2	263·0	+0·2	...	4·73	...
1856·09	Jacob	261·1	259·9	+1·2	4·70	4·87	−0·17
1857·96	„	258·1	257·4	+0·7	4·49	5·01	−0·52
1861·03	Powell	253·4	253·6	−0·2	4·86	5·22	−0·36
1870·92	Russell	242·1	242·8	−0·7	5·46	5·85	−0·39
1877·03	Ellery	237·3	237·3	0·0	(5·0)	6·19	(−1·19)
1878·19	Russell	237·0	236·3	+0·7	6·138	6·26	−0·122
1879·93	Hargrave	237·3	234·9	+2·4	5·44	6·37	−0·93
1880·45	Russell	234·7	234·5	+0·2	6·295	6·40	−0·105
1880·58	Tebbutt	233·6	234·4	−0·8	6·42	6·41	+0·01
1882·18	„	233·0	233·1	−0·1	7·01	6·53	+0·48
1885·19	„	230·5	230·8	−0·3	7·10	6·75	+0·35
1886·901	Pollock	229·9	229·6	+0·3	6·63	6·82	−0·19
1886·909	„	230·8	229·6	+1·2	6·85	6·82	+0·03

Further Researches on Stellar Parallax by the Photographic Method. By Professor C. Pritchard, D.D., F.R.S.

In my last communication to the Society I gave the results of an investigation of the parallax of the two components of 61 *Cygni*, each being referred to four comparison stars independently. These eight independent results cohere in a remarkable manner, and together furnish a mean value of the parallax identical with that derived from the determinations of Bessel and subsequent astronomers.

Encouraged by the hopefulness of this new method, I entered on the discussion of the parallax of μ *Cassiopeiæ* and of the Pole Star. The necessity, however, of improving the mechanism of the De La Rue equatorial, now much worn by long and honourable service, greatly interrupted the continuity of the work. Aided by the continued generosity of the original donor this instrument was ultimately restored to very effective order by Mr. Simms, and since its restoration the research has continued without avoidable interruption.

On each of fifty-three nights, four photographic plates were taken of μ *Cassiopeiæ*. The exposures varied from five to ten minutes. About 3 per cent. of these plates were found to be injured and unsuitable for the inquiry. This number of defective plates is so small that, in the work to be presently described, I have adopted the method of taking two impressions on the same plate slightly moved in position, and in this way both labour and expense are economised. Details of all these

researches will in due time be published by the University in a third fasciculus of the Oxford Observatory proceedings. Awaiting this publication I here give simply the results of the investigation.

Two suitable stars, here called (A) and (B), were selected as comparison stars, of approximately the 8th and 10th magnitudes. The resulting parallaxes are as follows :—

From star (A) $\pi = 0''{\cdot}0501 \pm 0''{\cdot}0270$.

From star (B) $\pi = 0''{\cdot}0211 \pm 0''{\cdot}0235$.

If a correction for the adopted value of the proper motion of μ be omitted, then the respective values are

From star (A) $\pi = 0''{\cdot}0677$.

From star (B) $\pi = 0''{\cdot}0429$.

These parallaxes are extremely small, and, taking into account the large proper motion of μ *Cassiopeiæ*, are interesting. Bessel, in 1816, investigated the parallax of this star by means of differences of right ascension on seventy nights, but he arrived at a *negative* value of $0''{\cdot}12$. It is, however, both proper and interesting to remark that this research and its result apply to a time long anterior to the introduction of the heliometer in 1829. In 1856, Professor Otto Struve obtained a parallax of this star by means of micrometrical comparisons, amounting to $0''{\cdot}342$; a quantity well within the compass of Bessel's method in 1816.

On reviewing the laborious processes adopted for the determination of the parallax of the preceding stars, it occurred to me that it would be a matter both of interest and importance to inquire what results would be obtained, had the measures been confined to a few nights only, when 61 *Cygni* and μ *Cassiopeiæ* were respectively at their greatest and least apparent distances from the comparison stars selected. Accordingly this method was applied first to 61 *Cygni*, when ten nights of maximum and minimum distance were selected from the entire group of eighty-nine nights. The result was a parallax of $0''{\cdot}4089$, as compared with $0''{\cdot}4321$ from the entire series.

The approximate identity of these results induced me to still further reduce the number of nights to five in the case of μ *Cassiopeiæ*, and these gave relatively to the two comparison stars mentioned above the respective parallaxes of $0''{\cdot}055$ and $0''{\cdot}095$, in place of $0''{\cdot}053$ and $0''{\cdot}021$. The probable errors, however, as was to be expected, are sensibly increased.

Bearing in mind the unavoidably approximate character of even the most elaborate investigations of stellar parallax, and especially when set side by side with the results obtained by this curtailed method, I have resolved (in ordinary cases) to abandon the very laborious processes applied in the case of 61 *Cygni*, and henceforth to limit the observations to five nights in each of four periods of the year, indicated by the position of the paral-

lactic ellipse. It is hoped that by this process the parallax of from ten to fifteen stars at the least will be determined within the year.

Forming my expectations from the experience of the past, I am led to hope that the parallaxes of all stars will in general be determinable by this method when they are not less than the thirtieth of a second of arc; for I find from the calculations of actual instances, that the probable error of a single night's measure of a "distance" does not sensibly exceed the tenth of a second; and inasmuch as the square root of the weight of π derived from the solution of a typical normal equation is 3·6, the probable error of π will not exceed the thirtieth of a second.

In the first instance I propose to apply this method systematically to all those stars between the magnitudes of $1\frac{1}{2}$ and $2\frac{1}{2}$, which attain at Oxford a sufficient altitude, and in fact it is already in course of application to α, β, γ *Cassiopeiæ*, and to γ and ϵ *Cygni*.

Certain cosmical relations cannot be safely inferred excepting from the parallaxes of numerous stars, and for such purposes *classes* of sufficiently approximate parallaxes will be more valuable than somewhat more accurate determinations in isolated cases.

I had hoped to have completed by this time the final determination of *Polaris* by the more elaborate process applied to 61 *Cygni*. The serious interruptions which have been already alluded to necessitate the continuance of the measures until June next. Meanwhile, I may mention that the curtailed process of selected nights has given a parallax amounting to 0″·052; a value which, according to Mr. Maxwell Hall, is close to the mean 0″·043 of all the determinations made by preceding astronomers.

Photographs of the Nebulæ 57 *M. Lyræ*; 27 *M. Vulpeculæ*; *the Cluster* 13 *M. Herculis*; *and of Stars in Cygnus.* By Isaac Roberts.

57 *M. Lyræ.*

Seven photographs of this annular nebula were obtained between July 14 and 31, 1887, with exposures varying between 10 and 60 minutes' duration. The enlargements (one 3 times and the other 25 times) which I now submit are from the negative taken on July 31, with an exposure of 20 minutes. Each of the negatives exposed for 15 minutes and upwards shows with much density the ring. The central star is also visible on each, though it is faintly seen on some; the light is therefore, photographically, very active. The interior of the ring is filled with faint nebulous matter, thus confirming the character given of it by Sir J. Herschel; but there is no evidence

of resolvability as suggested by the Earl of Rosse, and asserted by Secchi.

The photographs show the ring about the extremities of the major axis fainter than the remainder, and that there are protrusions somewhat beyond a line that would form the ellipse quite symmetrical.

Sir J. Herschel * states that the 11th mag. star following is distant about the breadth of the ring from the nebula, but the photographs show it to be less than half that distance removed.

The Earl of Rosse † shows filaments round the outer edge of the nebula which the photographs do not, but all the negatives clearly show the central star, which is not indicated by Sir J. Herschel or the Earl of Rosse. They refer to the internal nebulosity which by the photographs is much fainter than the star, yet neither of them has seen it, and, therefore, the suggestion that the star is variable receives here some confirmation.

27 *M. Vulpeculæ.*

Seven photographs of this nebula also were obtained between July 31 and October 10 this year, with exposures varying between 15 minutes and 2 hours' duration; but the atmospheric and other circumstances during the opposition this year were unfavourable to long exposures, and the light of the nebula is very feeble. Therefore this photograph taken on August 27 last, with exposure of 90 minutes (enlarged 15 times), does not exhibit the details that could be shown under good conditions; but it is clearly an elliptical nebula, and the drawing of it by Mr. Lassell in the *Memoirs* of the Society for 1866 (omitting the stars and internal details) agrees well with the photographs, and so also does the drawing by the Earl of Rosse in 1861.

Cluster 13 *M. Herculis.*

The two photographs (enlarged 3 times and 15 times) are from a negative taken, with an exposure of 60 minutes, on May 22 of this year. Sir J. Herschel and the Earl of Rosse have given drawings of this cluster, but as the positions of the stars in them are only roughly indicated, they cannot usefully be compared with the photographs. Sir J. Herschel says * there must be thousands of stars in it; it does not come up to a nucleus, has hairy-looking curvilinear branches, indicates a globular form not much denser at the centre.

The Earl of Rosse says ‡ it seems to have a dark streak across the bright part, a little above the centre; dark spaces seen through mist

Several of these descriptions are confirmed by the photographs, but two prominent features are omitted by both observers, namely, the nebulosity of the individual stars and the cluster itself being involved in nebulosity.

* *Phil. Trans.* 1833. † *Ibid.* 1844. ‡ *Ibid.* 1861.

These features are best seen on the negatives, though they are also well shown on the enlargements.

Stars in Cygnus.

Admiral Mouchez presented to the Society four beautiful photographs, by the Brothers Henry, of stars in *Cygnus*. One of them taken on August 14, 1885, has A. R. $19^h\ 45^m$ and D. $35°\ 30'$. On August 23, 1886, I took a photograph of the same sky space, and on August 14 this year again another. These have been enlarged 3 times, and they serve to illustrate what has frequently happened in my experience of stellar photography—that with similar plates, exposed to a given sky space for an equal length of time, and apparently with equal clearness of sky, there are surprising differences in the number of the stars that can at any time be photographed.

In the three photographs to which reference is here made these differences are remarkable, and to enable us to appreciate them, I counted one-eighteenth (17·75) of the stars upon corresponding areas on each plate respectively, and by measurements and calculations founded upon these data arrived at the following results :—

1st. The number of stars upon MM. Henry's plate in 1885 equal	3124
2nd. The number of stars upon my plate of 1886, having a sky area coincident with that of MM. Henry's plate equal	5023
3rd. The number of stars upon my plate of 1887 with coincident sky area equal	16206

The exposures in each case were of 60 minutes' duration, yet the third plate has upon it more than five times as many stars as the first.

These facts point out one of the difficulties that will be frequently met with by those who will be participating in the formation of the projected international photographic chart of the stars which is intended to include stars down to the 14th magnitude, with exposures of 15 minutes; but I am not here suggesting that the difficulties cannot be overcome. These discrepancies may be due to several causes, mechanical, chemical, and atmospheric, acting differently at different times.

On the Measurement of Celestial Photographs. (Extract from a Letter to the President.) By Isaac Roberts.

I wish to ascertain if some of the Fellows of the Society would be willing to engage in the scientific work of stellar photography by determining from negatives—

First. Stellar parallax.

Second. Stellar proper motion.

Third. Stellar photographic magnitudes.

Fourth. Stellar colour and variability.

Fifth. Stellar work not particularised above.

May I therefore ask you to communicate to the Fellows the offer that I should be willing to place in their hands such negatives as would enable a limited number of them to conduct with the necessary accuracy the investigations enumerated in these suggestions?

The essential equipment required by any worker would be: 1st, a good position micrometer; 2nd, a microscope of simple construction with 1-inch and 3-inch objectives, a sliding stage 7 inches × 7 inches (a plate of glass would do), and a reflecting mirror beneath it.

With such inexpensive appliances as here named astronomical work of the highest accuracy could be done, without the costly equatorial and transit instruments, and without the physical exposure at night which is unavoidable in using them.

I would supply the negatives free of cost, and only stipulate in return that each worker should have the necessary knowledge and perseverance to pursue the investigations he undertakes, and that he should communicate the results to the Society in a form acceptable to the Council.

1887, *November* 7.

On the Appearances presented by the Satellites of Jupiter during Transit, with a Photometric Estimation of their Relative Albedos, and of the Amount of Light Reflected from the Different Portions of an Unpolished Sphere. By Edmund J. Spitta.

Since their discovery by Galileo in 1610, the satellites of *Jupiter* have met with much attention, both from the mathematical as well as the physical astronomer. It is not the purpose, however, of this paper to deal with the former class of investigation, and only with so much of the latter as strictly relates to the appearances presented by the satellites during transit.

It is needless to state that during superior conjunction the satellites have from times most remote presented appearances not satisfactorily accounted for; appearances, too, which do not seem to apply equally to all the satellites, or even in some instances to the same satellite in two successive revolutions.

Passing over the first observation of the kind by Cassini in 1665, the next is recorded by Maraldi in 1707, who wrote two memoirs to the Paris Academy upon the subject, his interest having been excited by witnessing the third satellite transit as a dark spot on April 4, but as a white one during the next revolution on April 11. From this time up to the present date numerous observers, amongst whom might be mentioned

Dawes, have witnessed anomalous appearances of one or other of the satellites—the second being always excepted, as will be referred to hereafter—and their recorded observations are to be found in the *Monthly Notices*, and in the Astronomical or other scientific journals.

Speaking briefly, from a large source of recorded data, and from notes of my own, extending over several years, the phenomena may be summarised as follows:—It appears notably that as the fourth satellite approaches the disc of *Jupiter* it becomes rapidly and increasingly fainter, until arriving at contact. When once upon the limb, it shines with a moderate brilliancy for about ten to fifteen minutes, no sensible difference in such duration of brilliancy being noticeable whether before, during, or after opposition. Following this, it suddenly becomes lost to view; an obscurity which, so far as my personal observations go, will not yield to the powerful light-grasp of a ten-inch reflector. Remaining in this obscurity for another period of about ten to fifteen minutes, it again becomes visible, but now as a dark spot, which shortly grows darker and darker until it equals the blackness of its own shadow on the planet.

These phenomena are not found to be exhibited by the second satellite, however; for this moon it appears has never been seen otherwise than white during transit. After having searched the literature of the subject, and before coming to this conclusion, I invited, through the medium of the Astronomical Papers those possessing any records of abnormal phenomena of the satellites in the shape of unpublished notes to forward them to me. Several replies were received concerning the other satellites, but no observations concerning the second.*

The appearances of the first and third satellites, however, differ again from the second and fourth. The former during transit is sometimes a light-steel grey, and at others so dark as to nearly merit the name of black (see foot-note to Series 2 of the experiments that follow), having often been described as "dark brown" or "dark grey," whilst the latter satellite has been seen distinctly white, and also so black as to be compared with the appearance of the fourth.

Tabulated for future reference these phenomena during transit become—for the

Fourth. That it is fainter than others on approaching limb; bright for first ten to fifteen minutes of transit;

* The only exception to this remark may be found in a paper by Sir W. Herschel, read before the Royal Society, June 1, 1797, in which he states: "It will hardly be necessary to take notice of a single observation at 163°, as from the proximity of the satellite to conjunction a mistake in the estimation may easily take place." So, too, with another observation, in which he thought the satellite looked "ashy" in colour. It is more than probable these appearances were subjective, as will be the more readily understood after the contrast experiments have been gone into.

lost for about the same time; reappears as a dark spot, becoming jet black.

Second. Always bright during transit; brilliancy least affected on approaching limb of planet.

Third. Sometimes becomes lost, reappearing as a dark spot; at others, remains white throughout.

First. After becoming lost, usually turns one of the shades of grey to nearly black.

Towards the end of 1884 it was thought that possibly the peculiar appearance of the fourth satellite and the dark tints of the others were merely optical, and that if it were possible to devise some means or arrangement to shut off the background of *Jupiter*—if not entirely, for the greater part—that the white appearance of the satellite would be restored. Accordingly the occulting eyepiece (*Monthly Notices*, 1884–5, vol. xlv. page 91) was arranged, with which it was hoped to have tried the experiment; but although the mechanical action of the shutters in the focus of a Ramsden eyepiece left nothing to be desired, still, when sufficiently closed, diffraction phenomena put aside all possibility of examining the satellite. Two other oppositions of the planet were occupied in further examinations of the satellites, not only during transit, but also in most parts of their orbit; but none of the observations added to the pre-existing knowledge of the subject.

In the summer of 1886, however, it occurred to me that some experiments on the effects of contrast might be made to ascertain the proportions of light which two bodies must possess, so that the smaller should appear black when superimposed on the larger one. It was thought then that if the facts and figures thus experimentally obtained were found to coincide with the relative albedos of the satellites themselves as compared with *Jupiter*, it would not be unreasonable to suspect that the abnormal appearances presented during transit depended on functional idiosyncrasies of the eye itself rather than to physical peculiarities of the Jovian system.

The following experiments, divided into series, were organised and conducted by a friend and myself:—

The Experiments.

The ratio of *Jupiter* to his satellites in linear diameter, being assumed as about thirty to one, several discs one-eighth of an inch in diameter were punched out of pieces of cardboard, previously prepared by painting with one, two, or more coatings of Indian ink flooded on. A disc of pure white cardboard was also obtained, $3\frac{3}{4}$ inches in diameter, fixed on a support of dead-black material and placed at a distance of about sixty yards from the observing telescope, a three-inch Tulley. The little discs or artificial moons were each provided with fine wires, so that

they could be held in front of the larger disc in the full light of a very powerful 3-inch condensing magic lantern, provided with three $2\frac{3}{4}$-inch wicks. One observer, for the first half of the experiments, had charge of the moons, and placed them upon the disc in succession, at first according to their number of coatings of ink, and afterwards, in repeating the experiments, in an irregular order; whilst the second observer viewed the effects produced in the telescope. The moon that appeared grey on the large disc with the fewest coatings of ink was noted, and that also which appeared as black as its shadow. Especial care was taken that the plane of each moon was at right angles to the collimation axis of the observing telescope, and that it had the same inclination to the light as the others: a necessity which was found at an early period of the experiments to be a very essential feature in the general arrangements.

The observers then changed places and the results were compared, when it was found that no subjective or personal influence interfered with the power of repetition.

The next point to be ascertained was the difference of reflective power in the moons which had appeared grey and black (as they will hereafter be termed) when compared with one similar in size of white cardboard; in other words, to ascertain their relative albedos to the disc of cardboard which had formed the background.*

A Pritchard's photometer was obtained, being especially made by Sir Howard Grubb according to some suggestions afforded by the kindness of Mr. Plummer, of Oxford University Observatory, who carefully examined the uniformity of the wedge itself throughout its entire length and evaluated it also for magnitude, and who merits the writer's warmest thanks for placing his experience so liberally at his disposal. This was attached to the occulting eye-piece already referred to, in such a manner that its shutters could be utilised at the same time as the wedge.† Owing to the focal length of the Tulley telescope, as well as its mounting being found unsuitable for the present purpose, a $2\frac{1}{4}$-inch object-glass of specially short focus was obtained and mounted on a very firm cast brass stand. The tube had no movement in azimuth, save but for a very limited amount of adjustment, but changes in its position with respect to altitude were possible, and were ascertained by a vernier and circle. Clamping arrangements of the firmest description were added.

The original intention was to compare the moons in the same field one with the other at the same time, but, as related by Professors Pickering and Pritchard with respect to the photo-

* The best definition of albedo is Seidel's, who thus defines it: "Albedo is the proportion diffusedly reflected by an element of surface of the (solar) light incident on such element," which in other words is the "relative capacity for reflection of diffused light from equal areas."

† For information concerning other details connected with this arrangement of the Pritchard's photometer see *The Observatory*, No. 129, page 389.

metry of double stars, the peculiar errors which the presence of one object in the field produces on the appearances (photometrically) of another, on the one hand; and the loss in the intensity of the light which was found to take place from the centre to the edges of the beam of light proceeding from a smaller condensing lantern used in preference in these determinations to the larger one, on the other, rendered this method insecure.

To meet this difficulty an arrangement was contrived and made which placed each moon, as it came under observation, in absolutely the same position as its predecessors with respect to the focal axis of the lenses of the lantern and the beam of light; but to ensure no possibility of movement passing undetected, the shutters of the occulting eyepiece were arranged that each moon should occupy the same position in the field, and the readings of the vernier proved that no movement of the tube had taken place unnoticed. With the arrangements completed, the appearances of the little moons in the wedge were studied on several occasions, for it must be remarked that they were found to be very different from those afforded by the examination of points of light such as is given by the real satellites, or by the stars; upon which nearly three months had been previously spent in acquiring familiarity with the instrument. This point has a special bearing, as will be seen hereafter.

Before making the final comparisons the apparatus was rearranged in such a manner that at every three or five observations a fresh extinction should be made of the white moon, in case any waning or irregularity of the light should have unknowingly occurred in the interval. This plan (although it was found afterwards not to have been necessary, the lamp having burnt so steadily) was carried out through the final determinations, the mean of over sixty extinctions being tabulated as follows: —
White with grey:

1	2	3	4	5	6
33	·58	·16	·58	·42	·05

White with black,

33	2·21	·12	·13	·87	·01

In the first column is shown the number of wedge extinctions; in the second the difference of magnitude; in the third the average deviation in magnitude from the mean of the observations themselves; in the fourth the resulting albedo of the two moons; in the fifth the deficiency of the albedo; in the sixth or last the difference of albedo produced by an error of ·1 magnitude.

This concluded the first series of experiments, which sufficiently established the following fact. When small discs of equal areas but of different albedo are placed upon a larger one

(the larger and smaller discs bearing in size the relation approximately of *Jupiter* to his satellites) they assume certain tints of shading, which directly depend upon their deficiencies of albedo, as compared with that of the background. Moreover, it further shows what difference of magnitude, and consequently what approximate difference in albedo, is necessary to produce appearances similar to the grey and black tints that the first, third, and fourth satellites have assumed during transit, an albedo of ·58 being necessary in the first instance, and ·13 in the second.

Series 2 was carried out with a somewhat different view, viz. to ascertain what effect on the general appearances was caused by the employment of backgrounds of the same reflective power but of different size. Accordingly all sizes were tried, from a foot in diameter down to a tiny disc exceeding the little moon by only one diameter; and, strange as it may seem, the contrast became the more impressive the smaller the background employed so long as it exceeded the smaller moon by about two diameters. It was also noticed with all sizes of backgrounds that when a moon of equal albedo was placed upon them it became invisible. Another peculiarity was also witnessed, that with small backgrounds, say of three or four times the diameter of the moon, although the same number of coatings of ink was required on the moon to make it appear black as its shadow, one coating less sufficed to make it commence to turn grey. When the background was reduced to less than two diameters the black or grey appearances were scarcely recognisable, and only a faint waning of the light was noticeable.

This set of experiments shows that the darkened tint of a disc when superimposed on another and larger one, be its size whatsoever, is due to the difference of albedo between the discs compared, and has little or no relation to the total quantity of light reflected by either. As the discs approach one another in size (so long as the greater exceeds the less by about two diameters) slightly less difference in albedo than ·42 will cause the smaller to appear grey, but a difference of ·87 is still required to make the dark moon (technically so called) appear as black as its shadow when superimposed on the larger disc.*

Series 3.—These experiments were instituted for the purpose of ascertaining the effect produced on a small disc by the approach of another and larger one as seen in a telescope.

The first experiment tried was that of moving the three-inch pure white disc towards the dark moon (technically so called), which it will be remembered was found to have an

* It is important to add that in making this statement it is absolutely necessary to have a shadow wherewith to make the comparison. We often through these experiments thought a moon worthy of such definition when in reality, on comparing with a shadow, it was found to be nothing of the sort. This doubtless accounts in a measure for the various terms employed by different observers for the tintings of the satellites during transit, for often there is no shadow wherewith to make comparison.

albedo of ·13 as compared with the larger one, both being strongly illuminated. As the larger one was advanced towards the smaller, it was distinctly noted that the latter steadily appeared to become less and less brilliant, until, when the two were nearly in contact, it was exceedingly faint and tinted looking. It will be seen hereafter a distinction will have to be drawn between the immediate effects due to the approximation of a large disc to a smaller one, and the immediate presence of a sphere with the same little moon; effects due to the loss of light at the edges and limb of a sphere in comparison with the uniform amount reflected by a disc.

The same experiments were repeated with moons of all values of albedo, from unity to that of 13, and although no definite figures can or could be actually given or arrived at, still it was evidently true that the amount of apparent loss of brilliancy depended upon the difference in albedo of the moon and the advancing disc. With a pure white moon there seemed no waning of brilliancy, but as the difference of albedo increased, so the effects of loss in brilliancy, tinting in fact, became the more apparent. The same experiments were repeated with backgrounds of all sizes, having the same reflective capacity; but so long as they were twice the diameter of the little moons the above description holds good. When, however, the advancing disc was reduced to the diminutive size of about two diameters, or less, the effect was but slightly noticeable.

The result then of these experiments, contained in this the third series, shows that if two discs (whose proportions are such that one exceeds the other by at least two diameters) are made to approach one another,* any apparent loss of brilliancy in the smaller is directly in accordance with the difference in albedo between it and the greater, and has no relation to any difference in the relative quantities of light reflected by either. Discs of equal albedo do not affect one another, and no well-marked effect seems noticeable until the difference of albedo between the discs exceeds ·42. Small discs only slightly affect others which are smaller still provided their diameters are sensibly equal.

Series 4 was undertaken for the purposes of witnessing the effects produced by placing the little moons in front of a sphere.

A $3\frac{3}{4}$-inch sphere of plaster-of-Paris was made and illuminated brilliantly. As in the previous series of experiments one observer had charge of the moons and the other of the telescope. The phenomena were witnessed at a distance of about sixty yards through the Tulley telescope by both observers, and noted.

It was found that the moons with the same albedo appeared black and grey as before, but, what was far more surprising, that

* The larger was advanced towards the smaller in preference to the opposite course, because it was found that shifting the smaller whilst examining it caused a disturbing effect on the mind. The results, however, would not be in the least affected.

all the phenomena of the dark transit could be completely reproduced. I have witnessed the real phenomena very repeatedly, but I did not contemplate a reproduction from the employment of such simple means.

Whilst the dark moon having an albedo of ·13 was advancing towards the artificial planet its light became fainter and fainter, but still of sufficient brilliancy to remain a bright spot when on the limb. Still continuing its journey across the artificial planet, and having arrived at an angle of about 65° measured from the centre,* it became lost to sight, reappearing on arriving at an angle of about 55° to 60° as a dark spot, which in a short time occupied in further progress became as black as its shadow. The effect was not a little surprising, seeing that it was totally unexpected. No changes in the phenomena were visible when the same experiment was repeated at different (so called) parallels of latitude in the plaster cast.

It became evident from the results of the previous experiments that these phenomena were due to progressive differences of albedo between parts of the sphere and the little moon which took place as the transit progressed; and as it was equally apparent that such changes could not have taken place in the albedo of the satellite, it was shown to be due to increase of brilliancy of the background. It was then determined to photometrically measure the differences in the amount of light reflected from the edges and limb, as compared to that reflected from the centre (technically defined) of a sphere; which differences are described in the following series.

Series 5.—The sphere was first examined with the occulting eyepiece, and the loss of light that was then plainly visible when the limb was compared separately and *immediately* with the centre (technically so defined) was felt to be far more than would otherwise have been anticipated. The contrast was a striking one. All kinds of means were devised to measure this loss photometrically, but after several attempts it was feared such could not be done with accuracy owing to the difficulty of preventing a portion of that already wedged being photometrised again unconsciously. Then also it was felt that actual points at definite angles were what was really required to be wedged, which of course with the present means was impossible. Ultimately the quadrant examined was divided and marked into ten perspective squares, each of which exactly fitted a similar one in the occulting eyepiece; and with this method, rude as it was, the following figures were obtained. They are not, however, so trustworthy as those subsequently obtained and described further on, which I believe to be as accurate as possible:—

* These angles are counted thus: "Centrality" is a term used in a technical sense, by which is meant a line joining the axis of the telescope to the true centre of the sphere: angles are counted from this zero to 90°, which is called the limb.

1	2	3	4
29°	·31	·75	·07
34	·36	·72	·07
39	·68	·53	·04
49	·87	·45	·06
56	1·40	·28	·06
78	2·56	·09	·07

In the first column is given the nearest approach to the mean angle of the perspective figure; in the second, the difference of light between the centre, or rather the district situated about it, and that angle, the loss in light being expressed in magnitude; in the third, the resulting albedo; and in the last the average deviation from the mean of the observations in magnitude.

Series 5*a*.—The object of this series was to detect and measure as accurately as possible, and by a different arrangement, the loss of light reflected from the limb and edges of an unpolished sphere, as compared with that reflected from the centre (technically so called) by employing a card placed at different angles to the incident light. The following arrangements were designed and made. A white card was held by an apparatus truly vertical and at right angles to the axis of the observing telescope, the light being thrown upon it from a reflector concealed from view. The rays proceeding from the reflector were arranged to be in the same vertical plane as the telescope, and the small loss which occurred from their impinging on the card with a trifling inclination or obliquity from below upwards was felt to be of no consequence, as it equally affected all positions of the card, and especially as it was not the total reflective capacity of the card that was being measured, but merely the difference in the amount of light reflected to the observer when the card was turned through different angles; for such were accurately known, the base of the instrument being provided with a graduated circle.

The mean of several observations is shown in the accompanying table:—

1	2	3	4	5
30°	·34	·01	·735	·265
40	·75	·02	·500	·500
50	1·09	·07	·367	·633
60	1·23	·04	·323	·677
65	1·46	·07	·261	·739
70	1·91	·04	·172	·828
75	2·19	·04	·133	·867
80	2·74	·04	·080	·920
83	3·27	·03	·049	·951
86 30′	3·87	·05	·027	·973

Column 1 gives the exact angle of observation; column 2 the loss in magnitude; column 3 the average deviation from the mean of the observations in magnitude; column 4 the resulting albedo; column 5 the loss of albedo at the same angle.

It will be seen from this table, as was foreshadowed in the previous one, that from centrality, as technically defined, to an angle of about 30°, there is practically no loss of reflected light, anyhow to a measurable amount, in the wedge photometer; but that from this angle to the limb the loss is by small increments at first, but after a little by rapidly increasing ones. The loss when reduced to *light* approaches very approximately the tangent of the angle.

This table brings prominently before notice when viewing a sphere as a whole—a mere disc in the telescope—that unconsciously all grades of albedo are blended simultaneously in the light that is reflected on to the retina. Owing to this being so different from the uniform albedo of a disc, it was thought desirable, if not actually imperative, to conduct even yet a further series of experiments to ascertain whether any different effects were produced from this cause upon a moon in transit; in other words, whether the results of the previous experiments and their facts and figures might not require modification when a background composed of such a combination of albedos was under consideration.

Series 6 was conducted for this purpose. The apparatus employed was a hemispherical sphere, a hollow-like shell, three and three-quarters of an inch in diameter, of plaster-of-Paris, supported by a hollow frame of papier-mâché, in its turn resting on a similar support of very thin wood, so arranged that different concentric rings could be removed at will, leaving the others undisturbed. The apparatus served its purpose admirably. The first movable portion was the centre zone (called in the future the "zone of equity," or "unity centre," from the fact that with the wedge it will be remembered no difference in the light reflected was perceptible from the centre to its edges), which extended from centrality, as technically defined, to a distance about 30° on each side. The second ring reached from 30° to 60°, the third from thence to an angle about 70°, whilst the portion remaining, really attached to the apparatus itself, consisted of but little else than the limb of the artificial planet. The illuminating arrangements and telescope employed were the same as before, the artificial planet being placed at a distance of about sixty yards. The moon selected was that having an albedo of ·13, and the following experiments as to the effects produced upon it by removal of one or more of the various zones were conducted:

A. Moon advanced towards the artificial planet with unity centre *in situ*, and with it removed. No apparent change in the appearance of little moon.

B. Moon placed on limb. No apparent change in appearance of little moon, whether unity centre *in situ* or removed.

C. Moon placed on zone about angle of 65° to 70°, where it usually exhibits the phenomenon of disappearance. No apparent change with centre, present or absent.

D. Moon left in same position and second zone removed. No apparent change, whether second zone was present or absent.

E. Moon placed on portion corresponding to about the angle of 60°. Little moon appeared *exceedingly black* when unity centre (which extended only to 30°, it will be remembered) was present, but recovered most of its brilliancy, appearing rather more tinted than usual when it was removed.

F. Moon untouched; second zone removed as well as centre. Moon recovered its original brilliancy.

The experiments, like all of the previous, were repeated with another observer at the telescope, and the results compared; but, as in the previous series with discs, it was found that no personal or subjective influence interfered with the power of repetition.

This concluded the sixth series of experiments, the summary of which may be advantageously considered with those of the whole, for I submit it will be seen by their careful consideration that much light has been thrown upon, if not a complete explanation afforded for, the apparently peculiar behaviour of all the satellites of *Jupiter* during transit, that is, provided the albedos of the four moons, as ascertained by the wedge photometer, are found to be numerically in accordance with those figures ascertained by these experiments to be requisite.

It must be first restated that for a small body or disc to appear as black as its shadow when superimposed on another (with certain limitations as to their respective sizes), there must be a difference of albedo approximately amounting to ·87, and a difference of about ·4 for it to appear grey (Series 1). Then it must be further borne in mind that it has been experimentally and photometrically proved that an unpolished sphere reflects less light at its limb and outer zones to that reflected at its centre one; that centre one extending, so far as the appreciation of the eye is concerned, from absolute centrality (technically defined) to an angle of 30°. If then a moon with a relative albedo of about ·13, say for convenience ·2, be advanced towards and upon a planetary sphere, the following effects are exhibited. As it approaches the limb the moon wanes in light, owing to the fact (Series 3) that it is advancing towards an object of superior albedo.*

* The fourth satellite having the smallest albedo, as will be hereafter seen, is the reason why it appears fainter on nearing transit than any of the others.

Proceeding on to the limb, it is found to be bright for a short duration—in other words, remains apparently illuminated, because the albedo of the limb is not of sufficient magnitude to give a difference of ·87, that required to make the smaller disc turn black, or even to permit of the small difference of ·4, the quantity which has been found necessary to make it change to grey. As it approaches to about an angle of 65° to 70°, the hitherto puzzling phenomenon of disappearance is exhibited; but this is now explicable by the consideration that such takes place when the moon is over part of the sphere, where its albedo and that of the satellite are approximately equal, and hence according to Series 2 no other effect could be expected.

Once past this position, and having arrived at an angle of about 55° to 60°, it will be remembered the moon suddenly turns dark, becoming rapidly as black as its shadow. Two causes are found to bring about this effect. They are: first, the simple fact that the moon is advancing towards a surface, the neighbouring zone of 50° to 60° possessing a superior albedo, and hence, according to Series 3, its brilliancy is diminished; secondly—and this is not the less remarkable, inasmuch as it accounts for the greater amount of tinting—because the central zone, under the circumstances peculiar to the situation, possesses such a power of affecting the eye that, although at some distance from the moon (which is still supposed to be at about the angle of 60°), it really acts more as if it *were itself* the background; and being so rich in albedo at once is of more than sufficient power to make the moon assume its blackened aspect. Thus, then, will it now be understood why this sudden and increasing darkness steals so rapidly over the satellite, because these two causes mentioned act *simultaneously* and *conjointly* upon it. This singular peculiarity — not noted previously with discs because of their uniformity in albedo—was detected and proved in the last or foregoing series by the simple process of removing the various zones in question, with the effects already noted; a proof in itself, I submit, of a crucial character.

Finally, and scarcely need it be added, the phenomena displayed by the other satellites are easily understood after what has been written. The second satellite is always white during its superior conjunction, because its albedo will be found to be so characteristically high, as rich almost as the background itself; that of the first satellite will likewise be found sufficiently so under most circumstances to enable it to maintain some superiority in colour over the background when in transit; that is to say, will usually present some shade of grey instead of jet-black when superimposed upon its primary. But as to the third, which seems to enjoy a certain amount of variability during transit, that satellite probably presents as its rotates on its axis sides of differing albedo; one of just sufficient intensity to enable it to maintain an aspect of whiteness; and the other, and greater part, with so much weaker an albedo—perhaps from

the presence of spots—as to enforce it to assume one of the varied tints of grey, or even to turn black, as Maraldi saw it in 1707.

In conclusion, with respect to any unique, rare, or other unusual phenomena presented by the satellites during transit, or even during their elliptic journeyings around their primary, it remains but to be pointed out that such can be easily conceived to arise from some of the effects of contrast belonging to one or other of the series of experiments before described; and this remark especially applies to the fourth satellite simply because, owing to its weak albedo, as will be shown hereafter, it is the moon most readily affected; and also in a measure this remark applies to the very different albedo which neighbouring portions of *Jupiter's* disc do themselves present, and which would give rise to modifications in "background" effects.

Obtaining the Relative Albedos of the Satellites with the Pritchard's Photometer.

The method employed to obtain the albedos of the satellites was as follows. Wedge-readings were taken of the different satellites on as many nights as possible during the year with the 6·5-inch Alvan Clark refractor, *Jupiter* being extinguished with the aperture reduced to one-eighth its linear diameter.

After the first few sets of observations had been secured, and the resulting albedos computed in the manner hereafter described, some doubts were thrown upon the accuracy of the results, notwithstanding their agreement *inter se*, on account of their differing so largely with those obtained at Harvard with the polarising photometer. As it seemed possible that an error might be found in the fact that the magnitude of *Jupiter* had been estimated up to this date, partly by observation and partly by calculation, based on the theory of apertures; and as the residuals of the observations themselves appeared satisfactory—being indeed less than those of the Harvard observations—the theoretical addition for the reduction of aperture became the subject of inquiry. If the law that the intensity of the light of a star as received in the focus of the telescope varies as the square of the linear aperture, the reduction of area in this case would entail the addition of 4·5 magnitude—the quantity actually employed—to that observationally obtained from the extinctions with the reduced apertures. But as the resulting albedos of the satellites did not present that accordance with those obtained by Professor Pickering, and inasmuch as the magnitudes representing the extinctions of *Jupiter* were manifestly too high, leaving a difference between them and the satellites that was evidently too small, it was felt (seeing the actual observations themselves were not apparently at fault) that the law in question was not applicable to the telescope employed. On referring to the literature of the subject, it was acknowledged not to comply with the required accuracy, and indeed Professor Pritchard, who had given the matter some consideration in his memoir on the wedge photometer, had

related that such law was not to be held in anything but in a general sense, as so much depended on surrounding circumstances.*

It became necessary then to inquire what was the correct magnitude to be added to the observations, to compensate for the loss of light caused by the reduction of aperture. It was ascertained in the following manner at the suggestion of Mr. Plummer, of Oxford University Observatory, whose experience with the wedge photometer is so considerable.

A star was to be selected of such magnitude as to enable the photometer to extinguish its light at the thick end of the wedge with the full aperture, and at its thin end with the aperture reduced to one-eighth its linear extent. By this simple but ingenious means it will be seen the interval of the wedge itself between the extinctions corresponds to the loss of light by the reduction of aperture, and this too without the adoption of any theoretical law or computation whatever. Two stars were selected, *Polaris* and δ *Leonis*.

The following table gives the actual extinctions :—†

Polaris.		δ *Leonis.*	
Full Aperture.	One-eighth.	Full Aperture.	One-eighth.
8·06	1·47	7·26	0·61
7·80	1·18	7·80	0·49
8·24	1·18	7·63	0·53
8·10	1·03	7·60	0·62
7·91	1·17	7·38	0·65
7·82	0·94	...	...
8·04	0·98	...	...
8·01	0.95	...	...
8·17	1·11	...	...
8·23	1·09	...	...
Mean 8·038	Mean 1·100	Mean 7·534	Mean 0·580
Difference 6·938		Difference 6·954	
In Mag. 4·93		In Mag. 4·95	

With Polaris 4·93
With δ Leonis 4·95
Adopted Mean 4·94 Mag.

The adopted mean then hereafter used was 4·94 magnitude: this

* *Memoirs of the Royal Astronomical Society*, vol. xlvii. pp. 387–391.

† In comparing the errors in the extinctions by the Clapham wedge with those of the Oxford, it must be remembered the former is divided into half-inches, the latter into inches. Errors in the former must therefore be divided by two to render such comparison exact.

was added to the extinctions of *Jupiter* with the reduced aperture instead of that obtained theoretically (which was 4·5 magnitude) being an addition of ·44 magnitude.

As many observations of the satellites were taken as the weather permitted, and the number of nights happened to be the same as utilised by Professor Pickering; but that observer on a few nights duplicated his observations, hence numerically they exceed those used in this case. The method of reducing the observations, somewhat operose, need not be here detailed, for it will be found fully described in a most comprehensive manner on pages 245 and 246 of the *Annals of the Harvard College Observatory*, vol. xi. 1878–79.

The whole of the observations being secured and reduced, it was found unexpectedly that they were again affected by some systematic error, for the resulting albedos of the satellites in two instances exceeded that of *Jupiter* itself, disregarding for the moment their utter discordance with those obtained at Harvard. No error in the computations being discoverable, after some loss of time it was determined to ascertain if the error had occurred from the fact that with these observations estimations of *points of light* as represented by the real satellites had been compared with extinctions of *Jupiter*—an object of *sensible area*. Previous experience showed, as it has been pointed out, that some time had to be expended in acquiring the experience necessary with both classes of extinctions, for indeed with each the photometer appeared as a new instrument; and it was conjectured as possible that although comparing extinctions of points with points, or areas with areas, gave correct and reliable results, that perhaps when the one class of observations were compared with the other, systematic errors might be introduced which would vitiate the conclusions.

To devise a means of ascertaining this point was very difficult, but it was contrived in the following manner through the kind suggestion of Captain Abney.

Two holes were to be made—one as small as possible, to represent a point of light, and another of far larger dimensions. They were to be placed at as great a distance as possible from the observing telescope and illuminated. The difference obtained photometrically was to be compared with that obtained theoretically from a careful measurement of the holes with a micrometer. Two such holes were ultimately made and measured, one being $\frac{21}{10000}$ths of an inch and the other $\frac{33}{500}$ths of an inch diameter; or approximately the relations of *Jupiter* to his satellite, viz. about 33 to 1. The amount of light issuing through them was ascertained photometrically and measured theoretically. The same process of reducing the aperture was resorted to for extinguishing the light of the larger hole, and the same plan adopted (as before explained) for ascertaining the amount of light lost in using the diaphragm. The experience derived from previous experiments was carefully utilised (as to using the very same beam of light, its waning, &c.),

and an especially constructed arrangement was made to place each hole in exactly the same position as occupied by its predecessor with respect to the lenses and the axis of the observing telescope.

The following figures were obtained:—

1. **As ascertained by wedge:**

Amount of light in mag. passing through great hole ...	3·09
Amount to be added equivalent to that cut off by diaphragm	4·66
Total amount in mag. of great hole	7·75
Total amount in mag. of small hole	0·99
Resulting difference in mag.	6·76

2. **As calculated theoretically,** assuming one hole was 33 times the linear diameter of the other ... ... 7·59 mag.

Thereby showing that with the photometer there is a loss amounting to ·83 magnitude when a point of light is photometrically compared with an object of sensible area.

It was evident then that this systematic error was to be added to all the extinctions of *Jupiter*, and this is what has been done in the table that follows:—

1	2	3	4	5	6
I.	8·12	·656	8·13	·652	1″·081
II.	8·40	·715	8·27	·809	″·910
III.	7·88	·405	7·76	·453	1″·537
IV.	8·73	·266	8·89	·230	1″·282

In column 1 is shown the number of the satellite; in column 2 its difference in magnitude with that of *Jupiter* as obtained by these observations; in column 3 the resulting albedo; in column 4 the difference in magnitude between it and *Jupiter* as obtained by Professor Pickering; in column 5 his resulting albedo; and in column 6 the measured diameter of the satellite adopted by both observers.

These results, seeing they are obtained by instruments of entirely different character, are very reasonably in accord, but it must be borne in mind a slight modification would be entailed in each if the adopted diameters of the satellites were changed; and some discrepancy exists between observers on this point, their measurement being no easy matter.

Taking then for granted these figures approximately represent the relative reflective powers of the satellites as compared with *Jupiter*, it only remains to be said that their several relations are reasonably in accord with the requirements set forth in the contrast experiments of the previous sections, as necessary to exist to establish phenomena such as are exhibited by the real satellites during transit.

Reducing the whole subject to a short conclusion—which has involved no less than four years of work, as consecutive as the continually interruptive nature of the profession to which I belong has allowed, and the labour too of carrying out upwards of two thousand extinctions in one form or another—is this, that the perpetual whiteness of the second satellite, and the darkened tints of the others during transit (not to say in explanation of the casual appearances strange and unusual reported at other times) is due to differences in their relative albedo as compared with that of *Jupiter*, and is not dependent upon the relative quantity of light reflected by one or the other, or upon any physical peculiarities of the Jovian system.

In conclusion, I must once more be allowed to record my thanks to my friend Mr. Plummer for placing his many experiences so liberally at my disposal, and in addition for his having overlooked all the albedo computations; and also to my friend, the Rev. James Holroyde, who has kindly verified by far the majority of the contrast experiments.

Ivy House, Clapham Common, London, S.W.

The Total Solar Eclipse of 1887, *August* 19.

By Dr. Ralph Copeland.

Professor Bredichin, of Moscow, finding that the central line of the total eclipse of the sun on August 19 passed almost exactly over his country seat of Pogoste, near Kineshma, most hospitably invited the Council to nominate two members of our Society to become his guests for the purpose of observing the eclipse. The Rev. S. J. Perry was chosen as one representative of the Society, and the writer takes this opportunity of thanking the Council most heartily for having selected him as the other fortunate candidate. Thanks to the efforts of distinguished Russian *savants* and the representations of the British Foreign Office, every facility for the introduction of eclipse apparatus into Russia was afforded by the Minister of Finance at St. Petersburg.

Although the weather on the important morning was so unfavourable that no records of any scientific value were secured with the apparatus sent from Dun Echt Observatory, it may not be out of place to give a short account of the preparations that were made, and of the circumstances attending the eclipse itself.

Photographic methods seeming to offer the greatest facilities for securing unequivocal records, both of the forms and spectra of the solar appendages, it was resolved to dispense altogether with eye observations. The photographic apparatus consisted of the following parts, which were all carried by a massive equatorial mounting.

A 6-inch telescope of about six feet focal length, with a dense flint glass prism of about 12° angle in front of the object-glass formed an open spectroscope. This was for photographing the chromosphere as a series of more or less separated rings of different degrees of refrangibility. It would also have given sharp narrow spectra of any specially brilliant points in the prominences or chromosphere.

Riding on this telescope was a star spectroscope with a 2-inch object-glass to form an image on the slit. This combination was directed so as to point some minutes of arc clear of the Sun's limb, when his image was central in the other instruments, with a view to photographing the spectrum of the corona.

Secured to the long free end of the declination axis was a camera of four inches aperture and thirty-two inches focus. This camera is the one which was so successfully used for Lord Crawford, in India, by Mr. Davis in 1871, and by using it for short and very short exposures, it was hoped that it might again give good photographs of the corona and prominences.

Partly balancing the preceding instrument with regard to the declination axis was a landscape camera, fitted with a spool of Eastman negative paper, for securing such views of the corona as could be obtained with about one minute's exposure.

Clamped on the long-focus instrument was yet another camera of large aperture with a 5-inch × 4-inch plate. This was to have been exposed for nearly the whole time of totality to determine the extreme photographic extent of the corona. After some trials it was arranged that the cameras at the tail end of the declination axis should be worked by James Macpherson, the attendant from Dun Echt Observatory, whom Lord Crawford had very considerately sent with the party, while I looked after the pair on the declination side. Two of Professor Bredichin's pupils kindly undertook to note down the time for us.

To simplify the working of so many cameras one set of slides fitted both the 6-inch telescope and the 4-inch camera, while another set were common to the small camera and the star spectroscope. The mounting having been originally designed by Messrs. T. Cooke & Sons for an 8-inch telescope was not at all overloaded with this apparatus. Several features in this mounting afford such great facilities in setting up the instrument that they well deserve mention as specially desirable in stands designed for eclipse expeditions. They are:—Power of turning the whole head of the stand right round in azimuth and clamping and adjusting it in any position. The outside of the polar axis cradle is parallel to that axis, which can therefore be inclined at the proper angle under the guidance of a spirit-level and angle-gauge. The declination axis is provided with a spirit-level.

The detached bath-house at Pogoste having been placed altogether at our disposal was easily turned into so convenient a

dark-room that the necessary trials of plates were made with every comfort. A reflecting circle belonging to Professor Bredichin provided the time with all desirable accuracy for the work contemplated.

As the object-glass prism deflected the light about 8°, the 6-inch telescope had to be directed to a point at that distance from the Sun. By turning the refracting edge of the prism round the optical axis of the telescope this deviation can be made to take effect in any direction, but the most convenient direction is either along an hour circle or to a point in the same parallel as the object under observation. The latter position was chosen as being more likely to throw the spectra of the prominences clear of each other in photographs taken near the beginning and end of totality.* It also simplified the attachments for the small spectroscope and the cameras.

For some time before our arrival at Pogoste, on August 4, the weather had been very fine, but a heavy thunder-shower on the afternoon of the next day was the beginning of a complete change in the weather. For, although it was repeatedly clear just at sunrise, it was very seldom that uninterrupted views of the sun or stars could be obtained. At 5 A.M. on the morning to which we had all been looking forward for so many months, the sky was almost altogether overcast, but about the time of first contact the clouds separated so that the Sun shone brightly. But when about half the Sun was eclipsed the drifting clouds began again to thicken so quickly that some twenty-five minutes before the total phase the Sun was completely obscured. The daylight now began to lessen rapidly; this, together with the swiftly moving cloud-drift, indicative of a strong wind overhead, closely resembled the gathering of a thunderstorm. So close was this resemblance that it required some effort to bear in mind that the darkness was mainly due to the progress of the eclipse, and that in spite of the fading light the clouds might possibly be clearing away. As will be seen, this is exactly what happened, but the favourable change unfortunately came a few minutes too late. Not knowing how dark it might become, a couple of candles were kept burning on a table some ten feet behind the instrument. When the chronometer showed that totality had already commenced, I noticed that the candles cast a distinct shadow of the observer on the instrument. At the same time the sky gave so much light as to remove all fear of being inconvenienced by the obscurity. The candles were therefore blown out. The precious moments of darkness slipped away, until just at the very last instant of totality the eclipsed Sun, surrounded by a brilliant ring of corona, burst out through a small opening in the clouds. Apparently at the very same moment the light of the Sun broke forth. Every effort was made to

*Something might be gained in this respect by making the deflection take effect in the plane of the Moon's orbit.

obtain photographs, and it was not until the negatives were developed that all hope of having secured some traces of the corona and prominences were given up. As might be expected, the spectroscopic negatives of the narrow solar crescent show some of the chief lines of the spectrum, H and H_1 being easily recognised. The star-spectroscope, too, yielded a very fair spectrum, but it is merely that of daylight. Many negatives of partial phase were taken, but they only serve to show that the plates were in good order.

One circumstance may be mentioned as showing how near we were to one of the few spots where the eclipse was well seen. During totality I had noticed that the sky near the S.S.E. horizon, which was visible from my post, was quite clear, and tinged as if the sun were setting. A few days afterwards we learnt from the captain of the Volga steamer *Alaska*, which was then between Kineshma and Nischni Novgorod, that he had seen the whole of the total phase unimpeded by clouds. His position would about agree with the clear gap visible from Pogoste.

I cannot conclude without expressing my warmest thanks to Professor Bredichin for the hearty welcome which he and his whole family accorded to us in Russia.

Dun Echt Observatory :
1887, *November* 9.

The Total Solar Eclipse of August 19, 1887. By the Rev. S. J. Perry, F.R.S.

Although the clouds interfered most seriously with the observation of the solar eclipse on August 19, I feel it to be my duty, as a delegate of the Council, to lay before the Society a brief report of the manner in which their mission was carried out; and I trust that some at least of the details I am about to mention may not be found useless for future eclipse observers. Most of the Fellows will remember that our associate Professor Bredichin sent a very generous invitation to the Society, offering hospitality to any two of its members who might wish to observe the total eclipse, and that Dr. Copeland and myself had the honour of being nominated by the Council as the representatives of the Society.

The Astronomer Royal most kindly placed at my disposal the coronagraph and photo-spectroscopes used by Mr. Maunder in 1886; so I resolved at once to devote my whole attention to the photographic portion of our work. A full description of the instrument will be unnecessary. It will suffice to mention that two spectroscopes, with cameras attached, were fastened to the square tube of the coronagraph, and the same tube carried a

4-inch achromatic and two small finders, one of which gave a projected image of any bright object that might be in the field of view of the telescope. I removed the 4-inch telescope, which I did not think I could use advantageously, and replaced it by a second coronagraph of somewhat shorter focus than the first. The two small finders were exceedingly useful, as one served for fixing accurately the position of the instrument, and the other for retaining the Sun in the centre of the field. The coronagraph, which is the joint property of the Royal Observatory and of the Royal Society, is most unfortunately very incomplete, and much time was necessarily lost in correspondence before all the essential parts could be got together. Besides the Royal Society and the Astronomer Royal, I have to thank General Festing and Captain Abney for the loan of a most valuable $4\frac{1}{2}$-inch photo lens with camera and dark slides; Mr. Hilger for a 5-inch object-glass; Mr. Lockyer for a 2-inch photo lens; and Dr. Schuster for the tube of the second coronagraph. Having collected the parts I erected the instrument at Stonyhurst, strengthened the tripod stand, adapted it to the required latitude, and so arranged the two-prism spectroscope that a comparison spectrum might be taken on the same plate as the coronal lines. Mr. Maunder very kindly secured the same advantage for the one-prism spectroscope by a different arrangement; I shifted the camera and exposed different parts of the same plate, whilst he covered different parts of the slit. Experiments were then made with sensitised plates from different makers: the Ilford, Derby, Eclipse, and Isochromatic were those used. All gave good results. The Ilford plate I found most reliable for long exposures, and the Isochromatic was perhaps slightly more satisfactory for spectrum photography; but as I wished to make the photographic arrangements as simple as possible, I thought the Derby plate would suit me better altogether than any other. I therefore ordered a special set of quarter-plates to be prepared for the eclipse, the emulsion being identical with that used for the Greenwich dry plates, and I told the maker to back them carefully and to pack them in special boxes. Two dozen of these plates were cut into halves by my assistant for use in the spectrum cameras. With a narrow slit, and an exposure of one second, excellent spectra were obtained from clouds near the Sun, and an exposure as instantaneous as possible gave similar results with direct sunlight. The lunar spectrum required about two minutes for a strong picture, whilst the Moon itself was well photographed in half a second. Beach's developer was found to answer well for all purposes, and was carried already mixed in bottles, two bottles of each ingredient being taken in case of accident.

The instruments and chemicals were sent by steamer from Hull to St. Petersburg, Messrs. Wilson & Co. taking the greatest care in seeing them well stowed on board, and a letter from the Russian minister freeing them from all duty, and even

from examination on arrival at their destination. This letter was due in great measure to the forethought of Professor Struve, who took the greatest pains to smooth the way for the eclipse observers, and gave us a most hearty reception at his magnificent observatory at Pulkowa. Every assistance was rendered to us at St. Petersburg by Mr. Saunderson, and he also telegraphed to the directors of the Steamboat Company on the Volga to secure all facilities during our journey to Pogost. I have also to acknowledge the kindest attention from Sir R. Morier, British Ambassador at St. Petersburg, and from other members of the Embassy.

At Kineshma we were met by Professor Bredichin, who more than fulfilled the high expectations we had formed from the kindness already shown us in Russia. Pogost was placed entirely at our disposal, every comfort was supplied, and we enjoyed the precious advantage of being left entirely free to attend to our preparations, any number of workmen being near at hand to assist when needed. A fortnight was spent in mounting instruments, testing chemicals, and making final adjustments and arrangements. A very few things were damaged by the journey, and the watchmaker of Kineshma easily repaired the mischief. A Russian bath-house served excellently as a photographic hut, and we were well supplied with rain and spring water for washing our plates during the process of development. A large ice-house also formed part of the establishment, and would have been more useful had the temperature remained at the height we found it on arrival. Most fortunately we were joined a few days before the eclipse by Miss Brown, of the Liverpool Astronomical Society, and her cousin Miss Jeffreys, and the latter most obligingly and most efficiently took charge of the cameras of my spectroscopes during totality, thus leaving me entirely free to attend to the two coronagraphs. With the one-prism spectroscope I hoped to obtain on the same plate a spectrum of the corona and two solar spectra for comparison, and with the two-prism spectroscope I though I might secure two spectra of the corona, one with, and the other without, a comparison spectrum on the same plate. I found by rehearsals that by giving undivided attention to the coronagraphs I could with a clear sky obtain easily during the $2^m\ 10^s$ of totality twelve photographs of the corona with the following exposures: four of 1^s, two of 2^s, two of 5^s, and one each of 20^s, 40^s, and 55^s. I was also prepared to expose plates in each instrument, so that the position of the Sun's axis might be determined by two pictures of the solar crescent on the same plate. For the same object two pointers were photographed on each negative.

The morning of the 19th, like most of the mornings that immediately preceded it, was cloudy, but the clouds were broken, and we thus obtained occasional glimpses of the solar crescent before totality, during one of which I exposed a plate; but clouds prevented a second picture being obtained on the same plate.

Seeing the nature of the sky I was forced at the last moment to alter my previous plan, and I resolved on trying only the short exposures of 1^s, 2^s, and 5^s. But even in this I was again disappointed, for during totality there was not even a partial break in the clouds, except at the last moment, and then I exposed a plate with as little delay as possible, but a minute arc of the photosphere had already appeared in the heavens. Had I exposed this plate for a somewhat longer time I might have obtained a slight trace of the corona, but it could scarcely have been of any practical utility. The negative shows a less bright extension of the photospheric arc, which must, I think, be due to a prominence of the chromosphere. Several pictures were taken whilst the solar crescent was still very narrow, and the diffused light is much stronger and more extended on the convex than on the concave side of the crescent, but this probably is due to the imperfect sky combined with the greater intensity of the convex arc rather than to any appearance of inner corona. In the second negative one of the cusps is decidedly sharp and the other blunt, and there is a marked difference in this respect in the successive pictures; but as the crescent became wider all bluntness disappeared. During totality the darkness was not great, the clouds possibly diminishing the effect. At any time I could have read the face of a watch without much difficulty, but lamps were ready in case of need.

The disappointment at so meagre a result would in any case have been great, but we felt it more intensely as we saw what distress it caused the hospitable family, who had done so much to ensure our perfect success. Personally I have to acknowledge my great obligations, not only to Professor Bredichin and his family, but also to Dr. Copeland and Mr. Macpherson for their generous aid during the time of preparation.

Observations of Comets made at the Orwell Park Observatory in the years 1886–87. By John I. Plummer, M.A.

Comet VII. 1886 . . . (*Finlay.*)

1886.	Greenwich Mean Time.	Comet—Star. Δα	Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Nov. 18	6 21 28	+0 52·04	+ 7 36·1	6–6	20 10 47·49	9·3155	−22 41 20·5	0·9137	+1·72	+11·9	1
24	6 32 58	+1 46·26	− 2 13·4	7–7	20 39 35·13	9·3289	−20 49 17·2	0·9092	+1·74	+12·8	2
29	6 23 24	+1 11·30	− 3 2·6	8 8	21 4 17·81	9·2782	−18 55 39·9	0·9090	+1·77	+13·5	3
30	6 6 22	−2 19·51	− 3 38·1	3 3	21 9 15·91	9·2107	−18 31 9 1	0·9113	+1 80	+13·6	4
Dec. 14	6 37 39	−1 43·57	− 2 44·9	6–6	22 21 8·75	9·2513	−11 31 9 3	0·8898	+1·95	+15·0	5
16	6 53 56	+3 24·06	−10 35·6	6–6	22 31 32·30	9·2944	−10 22 5·1	0·8843	+1·96	+15·2	6
18	7 1 42	+2 8·14	− 2· 6·6	8–8	22 41 53·68	9·3084	− 9 11 27·5	0·8797	+2·00	+15·3	7
19	6 33 28	−1 57·44	+ 0 26·6	8–8	22 46 56·83	9·2100	− 8 36 17·3	0·8806	+2·04	+15·2	8
20	6 53 59	−1 37·89	+ 0 19·3	9 8	22 52 9·94	9·2765	− 7 59 38·6	0 8766	+2·05	+15·3	9
23	6 54 40	−2 17·95	+ 8 39·3	8–8	23 7 31·47	9·2657	− 6 10 10·0	0 8698	+2·11	+15·3	10
25	6 43 3	−0 52·98	+ 4 16·7	8–8	23 17 39·48	9·2163	− 4 56 47·2	0·8655	+2·14	+15·4	11
27	7 36 54	+1 37·75	− 2 30·7	7–7	23 27 55·70	9·3670	− 3 41 42·2	0·8573	+2·17	+15·5	12
28	8 12 14	−1 14·36	+ 2 58·4	8 8	23 33 5·00	9·4342	− 3 3 26·9	0·8529	+2·21	+15·4	13
29	8 5 34	−1 31·64	+ 7 45·5	8–8	23 38 3·67	9·4205	− 2 26 39·4	0·8511	+2·23	+15·3	14
30	6 29 19	+0 52·80	− 4 17·8	3–3	23 42 43·71	9·1348	− 1 52 40·5	0 8516	+2·24	+15·4	15

November 18.—Comet fairly bright but without marked nucleus.
November 29.—Windy, clock not well heard at times. November 30–December 30.—Comet faint, moonlight.
December 14–16.—Observations difficult owing to the proximity of a small star.
December 23.—Comet faint from haze.
December 27–29.—Observations interrupted by cloud; at times the comet was very faint.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Jan. 12	6 36 20	+1 8·05	− 3 3·8	8–8	0 44 57·12	9·1178	+ 5 44 18·3	0·8062	−0·56 − 5·1	16
20	6 54 18	−2 37·93	− 0 39·7	8–8	1 20 29·72	9·1854	+ 9 50 4·9	0·7776	−0·41 − 5·5	17
26	7 1 32	+4 6·01	− 5 54·9	8–8	1 45 39·96	9·2126	+12 31 34·1	0·7569	−0·37 − 5·5	18
Feb. 12	8 27 9	+1 23·08	+ 0 54·1	7–7	2 50 20·26	9·4549	+18 25 45·3	0·7349	−0·23 − 6·0	19
25	8 33 37	+1 7·85	− 2 35·8	6–6	3 33 45·13	9·4861	+21 25 46·3	0·7181	−0·22 − 6·3	20

January 12.—Comet faint, light clouds passing.
January 20–26.—The comet is still fairly bright but difficult to observe. The R.A. comps. are the more doubtful.
February 12–25.—Comet excessively faint.

Comet VIII. 1886 . . . (*Barnard, January* 23, 1887.)

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Feb. 13	7 19 3	−1 1·98	−1 26·8	5–5	20 6 55·93	9·5302	+37 59 31·7	0·8895	−1·40 − 3·3	21
16	7 19 44	−1 29·83	−4 16·9	7–7	20 16 39·26	9·5363	+39 49 22·3	0·8886	−1·39 − 3·9	22
Mar. 11	7 50 18	+2 31·00	+0 21·5	2–2	21 41 4·33	9·5590	+52 29 33·4	0·8848	−1·32 − 7·0	23
12	8 20 28	+1 13·07	−0 14·8	7–7	21 45 16·23	9·4774	+52 58 11·9	0·9011	−1·33 − 7·1	24
16	7 51 53	−0 19·86	+4 13·8	7–7	22 1 53·64	9·5811	+54 45 54·4	0·8783	−1·33 − 7·4	25
18	8 14 44	+2 0·72	−0 56·5	7–7	22 10 30·40	9·5283	+55 37 12·5	0·8896	−1·33 − 7·6	26
Apr. 27	11 48 39	−2 26·33	+5 32·8	7–7	1 17 22·61	$9·3488_n$	+65 34 43·5	0·8852	−1·54 − 9·4	27
May 14	11 40 13	+3 45·29	+6 21·8	8–8	2 31 7·83	$9·2377_n$	+66 33 27·4	0·8854	−1·53 −10·3	28
20	11 52 2	−5 18·93	+0 19·3	8–8	2 54 43·68	$9·3426_n$	+66 39 19·2	0·8818	−1·54 −10·2	29

February 13.—Comet faint from haze.
March 11.—Comet excessively faint, and the observation doubtful in consequence.
March 16.—The comet is small and faint but observation satisfactory.

Comet IX. 1886 . . . (*Barnard-Hartwig.*)

1886.	Greenwich Mean Time.	Comet—Star. $\Delta\alpha$	$\Delta\delta$	No. of Comps.	Comet's App. R.A.	Log. $(p\times\Delta)$	Comet's App. Dec.	Log. $(p\times\Delta)$	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Oct. 22	16 42 22	−2 6·29	+ 8 5·6	6–6	11 17 42·49	$9\cdot5231_n$	+ 4 3 43·1	0·8305	+0·97 − 7·8	30
Nov. 5	16 45 29	+0 20·93	+ 0 34·9	9–8	12 6 3·84	$9\cdot5173_n$	+ 8 0 40·6	0·8153	+1·03 − 9·2	31
7	16 43 55	+2 16·80	+ 1 46·7	8–8	12 14 57·02	$9\cdot5205_n$	+ 8 43 31·0	0·8130	+1·03 − 9·4	32
18	17 10 30	−1 50·10	+ 2 43·0	8–8	13 18 38·12	$9\cdot5212_n$	+13 18 46·2	0·7909	+0·88 − 8·8	33
18	17 18 58	−3 28·28	+ 1 21·5	5–6	13 18 40·49	$9\cdot5125_n$	+13 18 56·6	0·7880	+0·88 − 8·7	34
23	17 11 29	+0 58·74	− 1 59·0	9–9	13 58 27·51	$9\cdot5424_n$	+15 29 23·1	0·7876	+0·78 − 7·6	35
30	17 39 52	+1 32·09	− 7 2·9	8–8	15 7 30·34	$9\cdot5568_n$	+17 42 20·0	0·7829	+0·61 − 3·6	36
Dec. 1	17 30 6	−2 22·70	− 6 22·7	8–8	15 18 17·05	$9\cdot5670_n$	+17 51 47·2	0·7903	+0·58 − 2·5	37
2	17 28 9	−1 5·07	− 4 15·7	8–8	15 29 18·42	$9\cdot5715_n$	+17 57 51·7	0·7943	+0·57 − 1·7	38
4	17 38 6	+3 5·85	+ 2 48·9	8–8	15 51 44·89	$9\cdot5736_n$	+18 0 4·5	0·7965	+0·57 − 0·4	39
9	17 44 1	−2 31·59	− 3 11·5	8–8	16 47 22·41	$9\cdot5792_n$	+17 2 48·5	0·8142	+0·58 + 4·6	40
12	5 56 55	−1 11·39	+ 2 38·0	8–8	17 13 42·68	9·5775	+16 2 50·7	0·8300	+0·64 + 6·4	41
14	5 52 47	+1 33·83	+ 7 30·2	7–7	17 33 26·77	9·5761	+15 2 53·6	0·8254	+0·70 + 7·6	42
16	6 1 39	−1 59·73	+ 0 11·0	7–7	17 51 59·71	9·5738	+13 55 11·9	0·8270	+0·76 + 9·2	43
18	6 9 14	+3 43·67	+ 1 27·7	6–6	18 9 11·45	9·5716	+12 41 32·2	0·8288	+0·81 + 9·8	44
19	5 51 59	−0 7·78	+ 5 8·2	8–8	18 17 10·02	9·5676	+12 3 47·5	0·8231	+0·85 +10·6	45
20	6 6 48	+1 15·55	−10 31·7	8–8	18 24 59·31	9·5686	+11 24 18·7	0·8280	+0·87 +10·9	46

October 22.—Sky very hazy. The comet rather indistinct, being within the lunar halo.
November 5–December 9.—Windy, clock not well heard.
December 14.—Sky hazy, and the definition at this altitude not good.

1886.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Dec. 23	5 54 51	−1 50·41	− 5 35·5	8–8	18 46 15·23	9·5610	+ 9 25 46·5	0·8262	+0·97	+12·2	47
25	5 54 33	+0 55·71	− 1 21·4	8–8	18 58 59·37	9·5577	+ 8 6 32·2	0·8281	+1·03	+12·4	48
30	5 43 42	−1 7·61	+ 7 58·0	8–8	19 26 22·99	9·5468	+ 4 55 20·2	0·8322	+1·17	+13·3	49
31	5 46 44	+2 16·25	− 1 13·0	7–7	19 31 12·45	9·5475	+ 4 18 19·7	0·8338	+1·18	+13·2	50
1887.											
Jan. 2	5 39 33	+1 56·57	− 7 10·6	4–4	19 40 19·56	9·5424	+ 3 7 34·6	0·8354	−1·71	+ 5·0	51
8	5 51 14	−1 59·63	+ 0 46·7	4–4	20 4 0·38	9·5479	− 0 8 28·8	0·8418	−1·73	+ 3·2	52
10	5 48 34	+2 44·11	+ 5 16·0	6–6	20 10 53·45	9·5472	− 1 7 42·2	0·8431	−1·72	+ 2·8	53

December 23.—Sky hazy near the horizon and the comet at times, not well seen.
January 2.—Comet faint from haze and moonlight.
January 8.—Comet very faint owing to low altitude and haze.
January 10.—Comet faint and two of the comparisons are rather doubtful.

Comet II. 1887 . . . (*Brooks, January* 23, 1887.)

1887.	Greenwich Mean Time.	Comet—Star. Δα	Comet—Star. Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Feb. 12	7 37 10	−0 53·65	− 1 15·9	8–8	1 23 10·06	0·0810	+75 17 5·0	$0·0379_n$	−0·96	+10·9	54
13	8 13 48	+1 29·89	− 0 59·2	7–7	1 38 0·42	0·0795	+74 14 25·6	$9·6416_n$	−0·80	+10·7	55
15	7 49 28	−2 43·02	− 6 16·1	7–7	2 1 57·31	9·9792	+72 6 13·8	$9·9763_n$	−0·50	+10·2	56

February 12–13.—Windy, clock difficult to hear well.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Feb. 16	8 27 29	−0 35·56	− 6 31·1	8–8	2 12 21·00	9·9912	+70 57 9·8	9·2880$_n$	−0·45	+9·9	57
17	8 6 2	−0 54·91	+ 3 22·4	8–8	2 21 17·33	9·9363	+69 49 57·2	9·7414$_n$	−0·38	+9·5	58
21	8 10 2	+3 25·03	−10 2·0	3–3	2 49 53·44	9·8385	+65 10 54·1	8·9408$_n$	−0·31	+8·0	59
24	7 53 42	+1 44·17	− 9 31·2	2–2	3 5 40·85	9·7537	+61 43 13·5	8·6602	−0·28	+6·8	60
25	7 43 33	+3 42·14	− 7 9·1	8–8	3 10 12·30	9·7187	+60 35 14·9	8·6426	−0·29	+6·4	61
26	7 53 54	+3 29·51	− 0 3·9	8–8	3 14 28·54	9·7220	+59 27 3·3	9·5439	−0·29	+6·0	62
27	8 20 43	+2 10·66	+ 0 49·9	8–8	3 18 32·78	9·7491	+58 18 24·5	9·9672	−0·29	+5·6	63
28	7 53 43	+2 36·24	− 3 19·2	8–8	3 22 13·42	9·6944	+57 13 27·5	9·8167	−0·29	+5·2	64
Mar. 1	7 19 56	+2 33·16	+ 6 28·1	8–8	3 25 40·21	9·6148	+56 9 47·9	9·5382	−0·30	+4·8	65
2	7 27 34	−2 42·03	− 0 3·4	4–4	3 29 2·93	9·6213	+55 4 53·8	9·7801	−0·27	+4·4	66
6	8 25 5	+0 48·40	− 7 25·8	9–9	3 41 4·31	9·6822	+50 54 10·3	0·3100	−0·33	+2·9	67
10	7 47 54	−2 16·61	− 2 41·2	7–7	3 51 1·21	9·6032	+47 5 7·5	0·3195	−0·35	+1·3	68
11	8 39 48	−1 3·69	+ 9 16·9	8–8	3 53 23·98	9·6664	+46 8 36·9	0·4717	−0·37	+0·9	69
12	9 3 17	−2 1·66	− 5 6·4	8–8	3 55 38·34	9·6814	+45 13 38·1	0·5389	−0·37	+0·6	70

February 21.—Observation obtained with difficulty between clouds.
March 2.—Comet very faint from haze and moonlight. Observation somewhat uncertain.
March 6–30.—Comet rather faint in moonlight.
March 10.—Comet in close proximity to several small stars. Observation a little uncertain.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. $(p+\Delta)$	Comet's App. Dec.	Log. $(p\times\Delta)$	Red. to App. Place.	Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Mar. 14	8 30 28	−0 59·75	+ 8 1·5	8–8	3 59 48·49	9·6426	+43 30 46·4	0·5073	−0·40 −0·2	71
16	10 15 39	+1 19·07	− 5 23·6	6–8	4 3 56·69	9·6883	+41 47 8·1	0·7052	−0·43 −0 8	72
18	10 37 16	+2 20·48	+ 6 56·9	8–8	4 7 44·28	9·6763	+40 11 1 7	0·7481	−0·45 −1·5	73
23	8 15 48	+1 22·17	− 5 2·7	8–8	4 16 18·60	9 6024	+36 33 5·2	0·6081	−0 50 −3·0	74
25	9 50 42	−2 5·87	+ 7 36·3	8–8	4 19 41·16	9·6477	+35 8 23·6	0·7416	−0·50 −3·6	75
27	8 35 55	+1 34·96	− 5 27·7	8–8	4 22 45·41	9·6132	+33 51 12·1	0·6722	−0·54 −4·0	76
28	8 11 1	−1 20 49	+ 3 12·8	8–8	4 24 15·87	9·5916	+33 13 46·8	0 6521	−0·53 −4·3	77
30	8 52 58	+0 36·81	+ 4 25·2	9–9	4 27 19·77	9·6185	+31 58 32·5	0·7135	−0·56 −4·8	78
Apr. 10	9 52 19	+3 22·44	+ 8 50·8	4–4	4 42 37·35	9·6034	+25 58 28·3	0·8164	−0·65 −7·1	79
11	9 31 27	+2 44·05	− 6 41·7	8–8	4 43 54·75	9·6049	+25 29 22·4	0 8053	−0·66 −7·2	80
15	9 5 49	+1 12·30	− 6 23·7	3–3	4 48 58·26	9·5990	+23 38 32·6	0·8013	−0 68 −7·8	81
16	9 7 8	+0 28 03	+ 5 9·8	8–8	4 50 13·51	9·5976	+23 12 8·1	0·8053	−0·68 −8·0	82
17	9 23 52	−1 17·17	− 8 41·2	8–8	4 51 28 96	9·5945	+22 45 9·9	0·8187	−0 68 −8·1	83
20	9 15 54	−1 11·71	+ 3 26·1	6–6	4 55 8·08	9·5906	+21 28 56 7	0·8220	−0·70 −8·5	84
23	9 24 10	−2 21·97	− 0 4·5	5–5	4 58 44·50	9·5832	+20 15 53·3	0·8334	−0·71 −8·8	85

March 23–27–28.— Sky clear, a high wind prevailing.
April 10.—Comet excessively faint upon the Moon rising.
April 11.—Definition bad.
April 20–23.—The comet has become very faint and of low altitude. The R.A. comparisons are rather uncertain.

Comet III. 1887 . . . (*Barnard, February* 16, 1887.)

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Feb. 28	9 1 56	−1 20·59	+ 4 55·6	8-8	4 43 18·03	9·4402	+22 52 11·7	0·6882	+0·10	−6·8	86
Mar. 13	8 34 46	−1 8·39	+ 2 14·6	8-8	3 37 24·29	9·5962	+32 7 12·7	0·6752	−0 47	−3 8	87
14	9 11 32	+1 35·48	+ 0 53·2	5-5	3 34 35·54	9·6245	+32 27 13·0	0 7187	−0·51	−3·8	88
16	8 44 14	+3 31·71	+ 3 47·6	7-7	3 29 37·55	9·6204	+33 2 13·7	0·6990	−0·58	−3·8	89
18	8 58 4	+1 16·95	+ 2 26 8	7-7	3 25 11·14	9·6341	+33 32 40·0	0·7235	−0·62	−3·8	90
19	8 33 2	−2 30·15	+ 3 13·0	8-8	3 23 12·24	9·6276	+33 45 59·8	0·7012	−0·63	−3·9	91
23	9 0 2	−2 16·45	+10 6·5	8-8	3 16 2·12	9·6451	+34 33 20·0	0·7501	−0·73	−4·1	92
27	9 21 53	−1 21·82	+ 2 54·2	8-8	3 10 6·49	9·6430	+35 10 55·8	0·7906	−0·81	−4·5	93
Apr. 10	9 12 36	+2 47·47	− 0 29·7	3-3	2 55 10·80	9·6162	+36 39 46·4	0·8398	−0·99	−6 2	94

February 28.—Comet excessively faint from fog and moonlight. No central condensation visible.
March 14.—Sky hazy: the comet is a diffused mass of light and affords no distinct point for bisection.
March 16.—The comet was better seen and a very faint nucleus was discernible towards the following side.
March 27.—A faint star near the comet rendered the observation rather difficult and uncertain.

Comet IV. 1887 . . . (*Barnard, May* 12, 1887.)

1887.	Greenwich Mean Time.	Comet—Star Δτ	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. ($p \times \Delta$)	Comet's App. Dec.	Log. ($p \times \Delta$)	Red. to App. Place.		Comp. St r.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
June 9	11 11 31	−1 2·48	−5 19·0	8-8	16 4 17·81	8 5908	−11 3 21·6	0 8951	+2·07	+ 2·0	95
10	10 51 7	−1 53·79	+5 13·8	8-8	16 6 28·99	7·9455	−10 17 6 1	0·8924	+2 07	+ 2·2	96
12	11 37 5	−1 46·30	+3 56 7	8-8	16 10 59·75	8 9413	− 8 43 31·5	0 8846	+2·07	+ 2·8	97
13	10 58 3	+1 17·06	+0 34·2	8-8	16 13 10·87	8 4459	− 7 59 35 7	0·8827	+2·06	+ 2·9	98

June 9.—Comet small, fairly bright, and with distinct nucleus.

1887.	Greenwich Mean Time.	Comet—Star Δα	Comet—Star Δδ	No. of Comps.	Comet's App. R.A.	Log. $p \times \Delta$)	Comet's App. Dec.	Log. $(p \times \Delta$	Red. to App. Place.		Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
June 15	12 28 8	+1 20·97	+7 25·5	6–6	16 17 48·40	9·2323	− 6 28 18·4	0·8717	+2·06	+ 3·4	99
17	11 2 12	−1 1·07	+6 27·6	8–8	16 22 10·35	8·6556	− 5 5 30·1	0·8691	+2·06	+ 4·0	100
18	10 54 51	−1 53·33	−9 24·5	8–8	16 24 25·24	8·5582	− 4 24 32·8	0·8657	+2·07	+ 4·3	101
20	10 57 0	+1 16·09	+4 15·5	8–8	16 28 56·76	8·6523	− 3 4 9·6	0·8587	+2·06	+ 4·7	102
22	12 25 32	−1 24·16	+0 28·7	8–8	16 33 36·18	9·2612	− 1 46 5·7	0·8505	+2·07	+ 5·3	103
July 11	10 52 34	+0 11·05	−4 40·2	9–9	17 15 31·28	8·9775	+ 6 28 28·5	0·7996	+2·11	+10·0	104
12	11 29 33	−1 15·54	+6 46·8	9–9	17 17 42·21	9·1855	+ 6 44 23·7	0·8002	+2·12	+10·2	105
13	11 14 21	−5 22·07	+7 23·7	7–7	17 19 48·11	9·1259	+ 6 58 37·2	0·7975	+2·14	+10·5	106
14	11 19 1	+3 58·89	−0 11·5	8–8	17 21 55·30	9·1565	+ 7 11 58·9	0·7965	+2·11	+10·5	107
18	11 3 34	−4 17·36	+4 21·4	8–8	17 30 14·31	9·1195	+ 7 56 22·6	0·7904	+2·15	+11·6	108
19	11 40 25	+3 52·14	−5 59·3	8–8	17 32 21·30	9·2732	+ 8 5 22·4	0·7932	+2·12	+11·6	109
20	11 19 13	−3 11·85	+6 34·5	8–7	17 34 22·76	9·2051	+ 8 13 36·2	0·7901	+2·15	+11·9	110
21	11 25 14	−1 42·06	−8 40·0	9–9	17 36 26·24	9·2350	+ 8 20 47·6	0·7902	+2·14	+12·1	111
24	11 17 30	−3 10·89	+5 3·1	8–8	17 42 30·48	9·2281	+ 8 38 56·7	0·7879	+2·16	+12·7	112
27	12 11 54	+1 5·23	+0 42·8	8–8	17 48 36·44	9·3950	+ 8 51 3·1	0·7952	+2·14	+13·2	113
28	12 7 31	+3 3·90	+3 21·4	4–4	17 50 35·10	9·3901	+ 8 53 41·9	0·7945	+2·14	+13·3	113

June 15.—Comet faint, sky hazy.

July 13.—Windy, clock difficult to hear well.

July 20.—Comet faint and difficult to observe. Sky less transparent than usual.

July 27.—Comet faint and observation rather uncertain.

July 28.—The comet has become faint and difficult to observe, especially in declination, owing to its peculiar form. It is much elongated from N. to S., and narrow from W. to E. This peculiarity has been noticed on several occasions lately.

All the above observations have been made with a dark-bar micrometer and an equatorial refractor of 10 inches aperture. They are corrected for differential refraction throughout.

*Assumed Mean Places of Comparison Stars.**

Comet VII. 1886.

Comp. Star.	R.A. 1886·0. h	m	s	Decl. 1886·0. °	′	″	Authority.
1	20	9	53·74	−22	49	8·5	Equat. comparison with Arg. Oe_2 20264.
2	20	37	47·13	−20	47	16·5	Equat. comparisons with Arg. Oe_2 20832 and C.Z. 28388.
3	21	3	4·74	−18	52	50·7	Equat. comparisons with Arg. Oe_2 21180 and Lam. 1353.
4	21	11	33·62	−18	27	44·6	⅓ (Gr. 7 yr. 2411 + Arm_1 4607 + C.Z. 29215).
5	22	22	50·37	−11	28	39·3	Equat. comparison with 58 Aquarii.
6	22	28	6·28	−10	11	44·7	⅓ (Yarn. 9908 + Arm_1 4956 + Glasg. 5871).
7	22	39	43·54	− 9	9	36·1	Equat. comparisons with Lam. 3956 and $B.W._1$ 780.
8	22	48	52·24	− 8	36	59·1	Schj. 9392.
9	22	53	45·78	− 8	0	13·1	Lam. 4690.
10	23	9	47·31	− 6	19	4·6	⅓ (2 Yarn. 10242 + $B.W._1$ 142).
11	23	18	30·32	− 5	1	19·2	Equat. comparison with $B.W._1$ 302.
12	23	26	15·78	− 3	39	27·0	$B.W._1$ 491 (Lalande's R.A. is 0ˢ·75 greater).
13	23	34	17·15	− 3	6	40·7	Equat. comparison with Lam. 4769.
14	23	39	33·08	− 2	34	40·3	Equat. comparison with $B.W._1$ 812.
15	23	41	48·67	− 1	48	38·1	Equat. comparison with Lam. 9283.
	1887·0.			1887·0.			
16	0	43	49·63	+ 5	47	27·2	B.B. vi. + 5°·109.
17	1	23	8·06	+ 9	50	50·1	$B.W._1$ 356.
18	1	41	34·32	+12	37	34·5	$B.W._1$ 716.
19	2	48	57·41	+18	24	57·2	Equat. comparison with $B.W._2$ 1097.
20	3	32	37·50	+21	28	28·4	$B.W._2$ 655.

Comet VIII. 1886.

	1886·0			1886·0			
21	20	7	59·31	+38	1	1·9	¼ (3 $Arm._2$ 2596 + Lal. 38806).
22	20	18	10·48	+39	53	43·0	*γ Cygni, Newcomb. Stand. Cat.* 905.
23	21	38	34·65	+52	29	18·9	Arg. $Oe._1$ 22732–3.
24	21	44	4·49	+52	58	33·8	Arg. $Oe._1$ 22887.
25	22	2	14·83	+54	41	48·0	½ (Arg. $Oe._1$ 23418–9 + Rümker 9852).
26	22	8	31·01	+55	38	16·6	Equat. comparison with Arg. Oe_1 23565–6.
27	1	19	50·48	+65	29	20·1	Lal. 2540. Orange-coloured star = No. 19 Chambers' Catalogue of red stars, *Monthly Notices*, xlvii. 6.
28	2	27	24·07	+66	27	15·9	Equat. comparison with Arg. $Oe._1$ 2644.
29	3	0	4·15	+66	39	10·1	Equat. comparisons with Arg. $Oe._1$ 3564 and B.B. vi. + 66°·249.

* These stars will be observed, as far as possible, on the Meridian at Harrow.—G. L. T.

Comet IX. 1886.

Comp. Star.	R.A. 1886·0. h m s	Decl. 1886·0. ° ′ ″	Authority.
30	11 19 47·81	+ 3 55 45·3	¼ (Gr. 7 yr. 1377 + Arm.$_1$ 2477 + Glasg. 2943 + Sant. 784).
31	12 5 41·88	+ 8 0 14·9	Yarn. 5085 (B.W.$_1$ 49, which is the same star, has greater declination by 3′ 6″·8).
32	12 12 39·19	+ 8 41 53·7	¼ (Gr. 6 yr. 793 + Arm$_1$ 2636 + Sant. 838 + Lal. 23048).
33	13 20 27·34	+13 16 12·0	Equat. comparison with ✶ 34.
34	13 22 7·89	+13 17 43·7	⅕ (2 Glasg. 3382 + Schj. 4814 + B.W.$_1$ 325 + Lal. 24912).
35	13 57 27·99	+15 31 29·7	B.W.$_2$ 1229.
36	15 5 57·64	+17 49 26·6	B.W.$_2$ 80 (B.W$_2$. 53 is the same star with an error of 1^m).
37	15 20 39·17	+17 58 12·4	Lal. 28144.
38	15 30 22·92	+18 2 9·1	½ (Gr. 9 yr. 1392 + Yarn. 6424).
39	15 48 38·48	+17 57 16·0	½ (B.W.$_2$ 1176 + Lal. 28961).
40	16 49 53·42	+17 5 55·4	Equat. comparison with B.B. vi. + 17°·3107
41	17 14 53·43	+16 0 6·3	⅓ (2 Arm.$_2$ 2043 + B.W.$_2$ 365).
42	17 31 52·24	+14 55 15·8	½ (B.W.$_2$ 929 + Lal. 32124). The mean of Bessel's rather discordant observations is taken. It does not agree with Lalande's).
43	17 53 58·68	+13 54 51·6	½ (2 Arm.$_2$ 2136 + B.W.$_1$ 1092).
44	18 5 26·97	+12 39 54·8	B.W.$_1$ 67.
45	18 17 16·95	+11 58 28·8	½ (Wash. Obs. + Lal. 33895).
46	18 23 42·89	+11 34 39·5	½ (B.B. vi. + 11°·3478 + Rümker 6524).
47	18 48 4·67	+ 9 31 9·8	½ (Glasg. 4632 + Arm.$_2$ 2299).
48	18 58 2·63	+ 8 7 41·2	¼ (2 Glasg. 4689 + B.W.$_1$ 1445 + Lal., 35624).
49	19 27 29·43	+ 4·47 8·9	½ (Glasg. 4825 + Arm.$_1$ 4091).
50	19 28 55·02	+ 4 19 19·5	Lam. 4376.
	1887·0.	1887·0.	
51	19 38 24·70	+ 3 14 40·1	½ (Lam. 4559 + B.W.$_1$ 947).
52	20 6 1·74	− 0 9 18·7	½ (Lam 7343 + Piazzi 18).
53	20 8 11·06	− 1 13 1·0	Lam. 7361. The decl. of Lal. 38760, which is the same star, is 19″·4 greater.

Comet II. 1887.

	1887·0	1887·0	
54	1 24 4·67	+75 18 9·9	Equat. comparison with Fedorenko 268.
55	1 36 31·33	+74 15 14·2	⅓ (2 Rad.$_1$ 503 + Arg. Oe$_1$ 1866).
56	2 4 40·83	+72 12 19·7	Equat. comparison with Arg. Oe$_1$ 2705.
57	2 12 57·01	+71 3 31·0	Equat. comparisons with B.B. vi. + 70°·187 and + 71°·139.

Comp. Star.	R.A. 1887·0.	Decl. 1887·0.	Authority.
	h m s	° ′ ″	
58	2 22 12·63	+69 46 25·4	B.B vi. + 69°·155.
59	2 46 28·72	+65 20 48·0	Rad.$_1$ 814.
60	3 3 56·96	+61 52 37·9	Equat. comparisons with B.B. vi. + 61°·521 and 543.
61	3 6 30·45	+60 42 17·5	Arg. Oe$_1$ 3563.
62	3 10 59·32	+59 27 1·2	A. G. Zones 408.
63	3 16 22·41	+58 17 29·0	Arg. Oe$_1$ 3731.
64	3 19 37·48	+57 16 41·4	Arg. Oe$_1$ 3772.
65	3 23 7·36	+56 3 15·1	Lal. 6364.
66	3 31 45·23	+55 4 52·7	B.B. vi. + 54°·701.
67	3 40 16·24	+51 1 33·2	½ (Rad.$_1$ 1068 + Arg. Oe$_1$ 4135).
68	3 53 18·17	+47 7 47·4	⅓ (2 Arm.$_2$ 491 + Lal. 7322).
69	3 54 28·04	+45 59 19·2	Equat. comparisons with Rümker, 2024 and B.B. vi. + 45°·857.
70	3 57 40·37	+45 18 44·0	B.W.$_2$ 1181.
71	4 0 48·64	+43 22 45·0	B.W.$_2$ 1255.
72	4 2 38·05	+41 52 32·5	B.W.$_2$ 1296.
73	4 5 24·25	+40 4 6·3	Lal. 7752.
74	4 14 56·93	+36 38 10·8	B.W.$_2$ 259.
75	4 21 47·53	+35 0 50·9	½ (B.B. vi. + 34°·883 + B.W.$_2$ 416).
76	4 21 10·98	+33 56 43·8	½ (B.W.$_2$ 409 + Lal. 8346).
77	4 25 36·89	+33 10 38·3	Equat. comparison with B.B. vi. + 33°·872.
78	4 26 43·52	+31 54 12·1	B.W.$_2$ 527.
79	4 39 15·56	+25 49 44·7	½ (B.W.$_2$ 822 + Lal. 8917).
80	4 41 11·37	+25 36 11·4	B.W.$_2$ 868.
81	4 47 46·64	+23 45 4·2	B.W.$_2$ 1024.
82	4 49 46·17	+23 7 6·2	B.W.$_2$ 1073.
83	4 52 46·82	+22 53 59·1	B.B. vi. + 22°·792.
84	4 56 20·49	+21 25 39·0	*Newcomb. Stand. Cat.* 239.
85	5 1 7·18	+20 16 6·6	*Newcomb. Stand. Cat.* 242.

Comet III. 1887.

	1887·0	1887·0	
86	4 44 38·52	+22 47 22·9	B.B. vi. + 22°·764.
87	3 38 33·15	+32 5 1·9	B.B. vi. + 31°·645.
88	3 33 0·57	+32 26 23·6	B.W.$_2$ 663.
89	3 26 6·42	+32 58 29·8	½ (B.W.$_2$ 499 + Lal. 6491).
90	3 23 54·81	+33 30 17·0	B.W.$_2$ 447.
91	3 25 43·02	+33 42 50·7	Equat. comparison with B.W.$_2$ 512.
92	3 18 19·30	+34 23 17·6	Equat. comparisons with B.W.$_2$ 306 and 381.

Comp. Star.	R.A. 1887·0.	Decl. 1887·0.	Authority.
	h m s	° ′ ″	
93	3 11 29·12	+35 8 6·1	½ (B.W.$_2$ 199 + Lal. 6055).
94	2 52 24·32	+36 40 22·2	Equat. comparison with B.B. vi. + 36°·608.
		Comet IV. 1887.	
95	16 5 18·22	−10 58 4·5	Equat. comparison with B.W.$_1$ 63.
96	16 8 20·71	−10 22 22·1	⅓ (2 Yarn. 6715 + B.W.$_1$ 111).
97	16 12 43·98	− 8 47 30·9	⅓ (2 Schj. 5761 + Lal. 29697).
98	16 11 51·74	− 8 0 12·7	B.W.$_1$ 184.
99	16 16 25·37	− 6 35 47·2	½ (B.W.$_1$ 272 + Schj. 5779).
100	16 23 9·36	− 5 12 1·6	⅓ (2 Schj. 5822 + Lal. 29982).
101	16 26 16·50	− 4 15 12·7	Schj. 5841.
102	16 27 38·61	− 3 8 29·8	Equat. comparison with Schj. 5851.
103	16 34 58·27	− 1 46 39·7	½ (Schj. 5901 + Lam. 5252).
104	17 15 18·12	+ 6 32 58·7	⅓ (2 Glasg. 4271 + B.W.$_1$ 236).
105	17 18 55·62	+ 6 37 26·8	Arm.$_2$ 2052.
106	17 25 8·04	+ 6 51 3·0	B.B. vi. + 6°·3434.
107	17 17 54·30	+ 7 11 59·9	B.B. vi. + 7°·3355.
108	17 34 29·53	+ 7 51 49·7	½ (Glasg. 4351 + Schj. 6332).
109	17 28 27·04	+ 8 11 10·1	Lal. 31996.
110	17 37 32·46	+ 8 6 49·8	½ (B.W.$_1$ 701 + Lal. 32337).
111	17 38 6·16	+ 8 29 15·4	B.B. vi. + 8°·3478.
112	17 45 39·21	+ 8 33 41·0	½ (Glasg. 4405 + Schj. 6418).
113	17 47 29·06	+ 8 50 7·2	B.B. vi. + 8°·3526.

Col. Tomline's Observatory, Orwell Park:
1887. *October* 19.

Occultation of Regulus by the Moon, observed at Dunsink Observatory. Communicated by Sir R. S. Ball, LL.D., F.R.S.

The occultation of *Regulus* by the Moon, which took place on October 12, was observed here with the 12-inch equatorial by Mr. Arthur A. Rambaut. The disappearance occurred at

$16^h\ 16^m\ 54^s{\cdot}2$ Dunsink mean time.

The star suffered no perceptible diminution of brightness as it approached the bright limb of the Moon. It appeared to enter undimmed for a short distance within the disc, and was then suddenly extinguished.

The reappearance occurred at

$17^h\ 20^m\ 36^s{\cdot}0$ Dunsink mean time.

The star flashed out in full brilliance with a suddenness almost startling.

Dunsink Observatory: October 17, 1887.

Occultation of Regulus. By the Rev. S. J. Johnson, M.A.

In contrast to the clouded state of the sky when *Aldebaran* was occulted on the 7th, a perfectly clear air prevailed during immersion of *Regulus* on the morning of the 13th. Disappearance $4^h\ 41^m\ 50^s$ morn. (time taken by sextant only.) But the point of interest was that the star assumed the appearance of visibility through the bright disc of the Moon during three beats of the chronometer ($1\frac{1}{5}$ second) before finally vanishing. Employed a power of 50 on $3\frac{1}{4}$ inches. *Mars* was included in the field of the finder, contrasting not a little in tint with the whiteness of *Regulus* and the yellow lunar disc. Emersion through haze at $5^h\ 47^m\ 19^s$. This might have been observed with the naked eye in a clear sky, as the star was readily visible to unaided vision directly afterwards.

Melplash Vicarage, Bridport:
October 22.

Note on the Latitude and Longitude of Maresfield Observatory.
By Captain W. Noble.

After the erection of my observatory I determined its geographical coordinates (by the best means then at my disposal) as follow :—

Latitude 51° 0′ 58″·3 N., and
Longitude 17·5 seconds E.;

and these quantities appear in every communication of mine to the Society (in which they were involved) up to the year 1874.

In 1873, however, the Ordnance Survey of the county of Sussex for the 25-inch map was completed, and at the end of that year I applied to the Director-General for the position of a bench mark made at the time. In reply I was furnished with a position (as it has since turned out) 3″·5 in error in latitude, and 10″·1 wrong in longitude = 355 feet and 646 feet respectively; but I altered my assumed coordinates in accordance with it.

Recently the present Director-General of the Ordnance Survey has obligingly furnished me with the absolutely accurate place of the bench mark of which I have spoken, and triangulating from it to the centre of my transit pier I find that to be situated in

Latitude 51° 0′ 59″·8 N., and
Longitude 17·11 seconds E.;

a determination in which I have the highest confidence.

Ephemeris for Physical Observations

Greenwich Noon		Angle of Position of ♃'s Axis. P	Latitude of Earth above ♃'s Equator. B	Latitude of Sun above ♃'s Equator. *B*	Annual Parallax. A−L.	L−O.	Longitude of ♃'s Central Meridian. (878°·25) I.	(870°·27) II.	Corr. for Phase.
1887.		°	°	°	°	°	°	°	°
Dec.	24	13·923	−2·990	−3·060	−6·202	100·800	21·23	86·11	+0·168
	29	13·552	2·999	3·058	6·794	101·779	91·76	116·74	·201
1888.									
Jan.	3	13·189	−3·007	−3·056	−7·358	102·728	162·34	147·42	+0·236
	8	12·834	3·015	3·054	7·889	103·644	232·98	178·16	·271
	13	12·489	3·023	3·052	8·383	104·525	303·67	208 95	·306
	18	12·157	3·031	3·050	8·837	105·366	14·42	239·79	·340
	23	11·838	3·038	3·048	9·247	106·163	85·23	270·70	·372
	28	11·535	3·046	3·045	9·610	106·913	156·10	301·66	·402
Feb.	2	11·251	−3·054	−3·042	−9·924	107·613	227·03	332·69	+0·429
	7	10·987	3·062	3·040	10·183	108·259	298·03	3·79	·451
	12	10·744	3·070	3·037	10·384	108·848	9·09	34·95	·469
	17	10·525	3·078	3·034	10·523	109·375	80·22	66·17	·482
	22	10·333	3·085	3·030	10·598	109·837	151·42	97·47	·489
	27	10·168	3·093	3·027	10·605	110·231	222·69	128·83	·489
Mar.	3	10·032	−3·101	−3·023	−10·541	110·555	294·02	160·26	+0·483
	8	9·926	3·109	3·020	10·404	110·806	5·43	191·76	·471
	13	9·852	3·117	3·016	10·191	110·982	76·90	223·33	·452
	18	9·810	3·125	3·012	9·901	111·080	148·44	254·97	·427
	23	9·801	3·132	3·008	9·532	111·100	220·05	286·67	·395
	28	9·825	3·139	3·004	9·085	111·042	291·72	318·43	·359
Apr.	2	9·882	−3·146	−2·999	−8·560	110·906	3·44	350·26	+0·319
	7	9·970	3·151	2·995	7·959	110·694	75·22	22·14	·276
	12	10·089	3·156	2·990	7·284	110·409	147·05	54·06	·231
	17	10·237	3·159	2·985	6·539	110·053	218·93	86·03	·186
	22	10·412	3·161	2·980	5·729	109·633	290·84	118·04	·143
	27	10·610	3·161	2·975	4·861	109·156	2·77	150·08	·103
May	2	10·827	−3·160	−2·970	−3·944	108·628	74·72	182·13	+0·068
	7	11·061	3·157	2·965	2·983	108·057	146·68	214·19	·039
	12	11·307	3·152	2·959	1·988	107·453	218·64	246·24	·017
	17	11·561	3·145	2·954	−0·972	106·829	290·58	278·28	+0·004
	22	11·817	3·135	2·948	+0·054	106·193	2·49	310·29	...
	27	12·071	3·123	2·942	1·081	105·557	74·37	342·27	−0·005
June	1	12·320	−3·110	−2·936	+2·098	104·932	146·20	14·20	·019
	6	12·559	3·095	2·930	3·093	104·329	217·97	46·07	−0·042
	11	12·784	3·078	2·924	4·056	103·757	289·67	77·87	·072

of Jupiter, 1888. By A. Marth.

Greenwich Noon.	Diameter Equat.	Diameter Polar.	Difference of limbs in A.R.	Difference of limbs in Decl.	Defect of illumination. Equat. preced. limb.	Defect of illumination. in A.R.	Defect of illumination. in Decl. north l.	*d*	*w*
1887.	″	″	s	″	″	s	″	°	°
Dec. 14	31·75	29·74	2·223	29·86	0·09	0·006	0·01	6·19	270·87
29	32·02	29·99	2·245	30·10	·11	·007		6·78	·76
1888.									
Jan. 3	32·32	30·26	2·269	30·37	0·13	0·009	0·01	7·35	270·65
8	32·64	30·56	2·295	30·67	·15	·010		7·88	·55
13	32·99	30·89	2·323	30·99	·18	·012		8·37	·45
18	33·37	31·25	2·353	31·34	·20	·013		8·82	·38
23	33·77	31·63	2·384	31·72	·22	·015		9·23	·33
28	34·20	32·03	2·417	32·12	·24	·016		9·59	·27
Feb. 2	34·65	32·46	2·451	32·55	0·26	0·018	0·01	9·91	270·21
7	35·15	32·91	2·487	33·00	·28	·019		10·17	270·15
12	35·66	33·39	2·525	33·47	·29	·020		10·37	270·10
17	36·19	33·89	2·564	33·97	·30	·021		10·51	270·05
22	36·74	34·41	2·605	34·48	·31	·022		10·58	269·99
27	37·31	34·94	2·647	35·01	·32	·022		10·59	269·92
Mar. 3	37·89	35·49	2·689	35·56	0·32	0·022	0·01	10·52	269·85
8	38·49	36·05	2·732	36·12	·32	·022		10·39	·77
13	39·10	36·61	2·776	36·69	·31	·021		10·17	·69
18	39·71	37·18	2·819	37·26	·29	·020		9·88	·59
23	40·31	37·75	2·862	37·83	·27	·019		9·52	·48
28	40·91	38·31	2·905	38·39	·25	·018		9·07	·35
Apr. 2	41·50	38·86	2·946	38·94	0·23	0·016	0·01	8·55	269·19
7	42·06	39·39	2·985	39·47	·20	·014	·01	7·95	269·01
12	42·60	39·89	3·022	39·98	·17	·012	·00	7·27	268·81
17	43·10	40·36	3·056	40·45	·13	·010		6·53	268·56
22	43·55	40·78	3·086	40·88	·11	·008		5·72	268·23
27	43·95	41·16	3·112	41·26	·08	·006		4·86	267·78
May 2	44·29	41·48	3·134	41·58	0·05	0·004		3·94	267·16
7	44·57	41·74	3·152	41·84	·03	·002		2·98	266·1
12	44·78	41·94	3·164	42·05	·01	·001		2·00	264·1
17	44·91	42·06	3·171	42·18	·00	·000		0·99	258·2
22	44·97	42·12	3·172	42 24	on following limb		on south limb	0·21	164·9
27	44·95	42 10	3·168	42·23				1·10	100·1
June 1	44·86	42 01	3·159	42·14	0·01	0·001		2·10	95·0
6	44·69	41·85	3·144	41·99	·03	·002		3·09	93·2
11	44·45	41·63	3·125	41·77	·06	·004	0·00	4·05	92·21

Greenwich Noon		Angle of Position of ♃'s Axis. P	Latitude of Earth above ♃'s Equator. B	Latitude of Sun above ♃'s Equator. *B*	Annual Parallax. A−L.	L−O.	Longitude of ♃'s Central Meridian. (878°·25) I.	(870°·27) II.	Corr. for Phase.
1888.		°	°	°	°	°	°	°	°
June	16	12·991	3·059	2·917	4·977	103·227	1·30	109·60	·108
	21	13·178	3·040	2·910	5·850	102·747	72·84	141·25	·149
	26	13·342	3·020	2·903	6·666	102·324	144·29	172·80	·194
July	1	13·481	−3·000	−2·896	+7·419	101·963	215·66	204·27	−0·240
	6	13·594	2·980	2·889	8·104	101·671	286·93	235·64	·286
	11	13·679	2·959	2·882	8·717	101·450	358·11	266·92	·331
	16	13·736	2·938	2·875	9·256	101·304	69·19	298·10	·373
	21	13·764	2·917	2·868	9·720	101·234	140·17	329·19	·411
	26	13·763	2·898	2·860	10·108	101·240	211·06	0·19	·445
	31	13·734	2·879	2·852	10·420	101·321	281·87	31·10	·473
Aug.	5	13·676	−2·860	−2·844	+10·658	101·477	352·59	61·92	−0·494
	10	13·590	2·842	2·836	10·822	101·708	63·23	92·66	·509
	15	13·476	2·825	2·828	10·914	102·011	133·79	123·33	·518
	20	13·335	2·809	2·820	10·936	102·383	204·28	153·92	·520
	25	13·168	2·794	2·812	10·892	102·821	274·71	184·45	·515
	30	12·975	2·780	2·803	10·785	103·323	345·07	214·92	·506
Sept.	4	12·757	−2·776	−2·794	+10·618	103·886	55·38	245·33	−0·491
	9	12·515	2·752	2·785	10·393	104·507	125·64	275·69	·470
	14	12·249	2·739	2·776	10·113	105·183	195·85	306·00	·445
	19	11·959	−2·726	−2·767	+9·782	105·909	266·01	336·27	−0·419

The angle A−L is the difference of the jovicentric longitudes of the Sun and Earth, reckoned in the plane of *Jupiter's* equator; L−O+180° the jovicentric longitude of the Earth reckoned from O, the point of the vernal equinox of *Jupiter's* northern hemisphere or the point of the ascending node of the planet's orbit on its equator.

Two values of the "longitude of ♃'s central meridian" are given for each date: the first, computed with the daily rate of rotation 878°·25, being intended for comparing the observations of the white spots in the neighbourhood of the planet's equator; the second, computed with the rate 870°·27, for the observations of the remnant of the great reddish spot in the planet's southern hemisphere. These rates, and the deduced longitudes, conform with those adopted in the ephemeris for the last apparition of *Jupiter* (*Monthly Notices*, vol. xlvii. page 40). The few passages of the great spot across the middle of the disc, observed in the course of the last apparition, render it probable that the spot will be found near the adopted zero meridian of the second system of longitudes. But as any observations of the white spots which may have been made during the last season have

Greenwich Noon.	Diameter Equat.	Diameter Polar.	Difference of limbs in A.R.	Difference of limbs in Decl.	Defect of illumination. Equat.	Defect of illumination. in A.R. following limb.	Defect of illumination. in Decl. south l.	d	w
1888.	″	″	s	″	″	s	″	°	°
June 16	44·15	41·34	3·101	41·49	·08	·006	·01	4·97	91·62
21	43·78	41·00	3·074	41·15	·11	·008	·01	5·84	91·20
26	43·36	40·61	3·043	40·76	·15	·010	·01	6·66	90 88
July 1	42·90	40·17	3 009	40·33	0·18	0·012	0·01	7·41	90·65
6	42·40	39·70	2·973	39·86	·21	·014	·01	8·09	90·46
11	41·87	39·21	2·935	39·36	·24	·016	·01	8·70	90·30
16	41·32	38·69	2·896	38·84	·27	·018	·02	9·24	90·17
21	40·75	38 16	2·856	38·31	·29	·019	·02	9·71	90·05
26	40·17	37·62	2·816	37·77	·31	·021	·02	10·10	89·96
31	39·59	37·07	2·776	37·22	·33	·022	·02	10·41	89·88
Aug. 5	39 01	36·53	2·736	36·67	0·34	0·022	0·02	10·64	89·81
10	38·43	35·99	2·697	36·13	·34	·023	·02	10·81	89·75
15	37·86	35·46	2·659	35·59	·34	·023	·02	10·90	89·70
20	37·31	34·94	2·622	35 07	·34	·023	·02	10·92	89·65
25	36·78	34·44	2·586	34·57	·33	·022	·02	10·88	89·62
30	36·26	33·96	2·552	34·08	·32	·022	·02	10·77	89·59
Sept. 4	35·76	33·49	2·519	33·60	0·31	0·021	0·01	10·60	89·56
9	35·28	33·04	2·488	33·15	·29	·020	·01	10·38	89·54
14	34 83	32·62	2·459	32 72	·27	·018	·01	10·10	89·52
19	34·40	32·22	2·432	32·31	0·25	0·017	0 01	9·77	89·49

not yet come to my knowledge, it is uncertain how far the chief white spot may have moved away from the neighbourhood of the zero meridian of the first system, and due allowance must be made for this uncertainty. The differences of successive values of the longitudes of 2′'s central meridian amount, for the intervals of five days, to 12 rotations in addition to the differences directly deduced; so that, for instance, the differences of the values for December 29 and December 24 are 4390°·53 and 4350°·63. The addition of the "correction for phase" to the longitudes of the central meridian gives the longitudes of the meridian which bisects the illuminated disc. A list of Greenwich times when these latter longitudes are 0° will be found further on.

The diameters of the disc, &c. depend on the same assumed values as in the ephemerides for preceding apparitions. The formulæ employed may be found in vol. xlv. page 508.

The inclinations γ and the ascending nodes Γ of the orbits of the four satellites of *Jupiter* in reference to the plane of the planet's equator are the following, the longitudes of the nodes being reckoned from O, the point of the ascending node of *Jupiter's* orbit on the equator.

	Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
	γ_1	Γ_1	γ_2	Γ_2	γ_3	Γ_3	γ_4	Γ_4
1888	°	°	°	°	°	°	°	°
Jan. 3	0·0113	285·3	0·4928	280·81	0·1401	248·79	0·3185	331·19
Mar. 3	·0112	283·5	·4927	278·90	·1391	248·42	·3178	331·27
May 2	·0110	281·7	·4927	276·99	·1381	248·03	·3171	331·35
July 1	·0109	279·7	·4926	275·07	·1372	247·62	·3164	331·42
Aug. 30	·0108	277·6	·4925	273·15	·1364	247·21	·3156	331·46
Oct. 29	0·0107	275·5	0·4924	271·23	0·1356	246·79	0·3147	331·48

The following is a list of Greenwich mean times, when the zero meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc.

	I. (878°·25)	II. (870°·27)		I. (878°·25)	II. (870°·27)
1887.	h m	h m	1888.	h m	h m
Dec. 26	20 17·4	19 7·6	Jan. 20	20 28·0	14 52·8
27	15 58·1	14 59·2	21	16 8·7	20 40·0
28	21 29·2	20 46·5	22	21 39·6	16 31·4
29	17 9·9	16 38·0	23	17 20·3	22 18·6
30	22 40·9	22 25·3	24	22 51·2	18 10·1
31	18 21·6	18 16·8	25	18 31·8	14 1·5
1888.			26	14 12·4	19 48·7
Jan. 1	14 2 3	14 8 4	27	19 43·4	15 40·1
2	19 33·4	19 55·6	28	15 24·0	21 27·3
3	15 14·1	15 47·2	29	20 54·9	17 18·7
4	20 45·1	21 34·4	30	16 35·5	23 5·9
5	16 25·8	17 25·9	31	22 6·4	18 57·3
6	21 56·8	23 13·2	Feb. 1	17 47·0	14 48·8
7	17 37·5	19 4 7	2	13 27·6	20 35·9
8	23 8·5	14 56·2	3	18 58·5	16 27·3
9	18 49·2	20 43·5	4	14 39·1	22 14·4
10	14 29·9	16 35·0	5	20 10·0	18 5·9
11	20 0·9	22 22·2	6	15 50·6	13 57·3
12	15 41·5	18 13·7	7	21 21·5	19 44·4
13	21 12·5	14 5·2	8	17 2·0	15 35 8
14	16 53·2	19 52·4	9	12 42·6	11 27·2
15	22 24·2	15 43·9		22 32·9	21 22·9
16	18 4·8	21 31·1	10	18 13·5	17 14·3
17	13 45·5	17 22·6	11	13 54·0	13 5 7
18	19 16·4	23 9·8		23 44·3	23 1·4
19	14 57·1	19 1·3	12	19 24·9	18 52 8

1888.	I. (878°·25) h m	II. (870°·27) h m
Feb. 13	15 5·4	14 44·2
14	10 46·0	10 35·6
	20 36·3	20 31·3
15	16 16·8	16 22·6
16	11 57·4	12 14·0
	21 47·7	22 9·7
17	17 28·2	18 1·1
18	13 8·8	13 52·5
	22 59·0	23 48·1
19	18 39·6	19 39·5
20	14 20·1	15 30·9
21	10 0·7	11 22·2
	19 50·9	21 17·9
22	15 31·5	17 9·3
23	11 12·0	13 0·6
	21 2·2	22 56·3
24	16 42·8	18 47·6
25	12 23·3	14 39·0
26	8 3·8	10 30·3
	17 54·1	20 26·0
27	13 34·6	16 17·4
28	9 15·1	12 8·7
	19 5·4	22 4·4
29	14 45·9	17 55·7
Mar. 1	10 26·4	13 47·0
	20 16·6	23 42·7
2	15 57·1	19 34·0
3	21 27·9	15 25·4
4	17 8·4	21 12·3
5	12 48·9	17 3·7
6	8 29·4	12 55·0
	18 19·6	22 50·6
7	14 0·1	8 46·3
	23 50·3	18 41·9
8	19 30·8	14 33·2
9	15 11·3	20 20·2
10	20 42·0	16 11·5
11	16 22·5	21 58·4

1888.	I. (878°·25) h m	II. (870°·27) h m
Mar. 12	12 2·9	7 54·1
	21 53·2	17 49·7
13	17 33·6	13 41·0
14	13 14·1	19 28·0
15	18 44·8	15 19·2
16	14 25·3	21 6·2
17	10 5·7	7 1·8
	19 55·9	16 57·4
18	15 36·4	12 48·7
19	11 16·8	8 40·0
	21 7·0	18 35·6
20	16 47·5	14 26·9
21	12 27·9	10 18·1
	22 18·1	20 13·8
22	8 8·4	6 9·4
	17 58·6	16 5·0
23	13 39·0	11 56·3
	23 29·2	21 51·9
24	9 19·4	7 47·5
	19 9·7	17 43·2
25	14 50·1	13 34·4
26	10 30·5	9 25·7
	20 20·7	19 21·3
27	16 1·1	15 12·5
28	11 41·6	11 3·8
	21 31·8	20 59·4
29	17 12·2	16 50·6
30	12 52·6	12 41·9
	22 42·8	22 37·5
31	8 33·0	8 33·1
	18 23·2	18 28·7
Apr. 1	14 3·6	14 20·0
2	9 44·0	10 11·2
	19 34·2	20 6·8
3	15 14·6	15 58·0
4	10 55·0	11 49·3
	20 45·2	21 44·9
5	16 25·6	17 36·1

1888.	I. (878°·25) h m	II. (870°·27) h m	1888.	I. (878°·25) h m	II. (870°·27) m
Apr. 6	12 6·0	13 27·3	Apr. 29	10 56·3	7 25·1
	21 56·2	23 22·9		20 46·5	17 20·6
7	7 46·4	9 18·5	30	6 36·7	13 11·8
	17 36·6	19 14·1		16 26·9	23 7·4
8	13 17·0	15 5·3	May 1	12 7·2	9 3·0
9	8 57·4	10 56·6		21 57·4	18 58·6
	18 47·6	20 52·2	2	7 47·6	14 49·7
10	14 28·0	16 43·4		17 37·7	24 45·3
11	10 8·4	12 34·6	3	13 18·1	10 40·9
	19 58·5	22 30·2		23 8·3	20 36·5
12	15 38·9	18 21·4	4	8 58·4	6 32·1
13	11 19·3	14 12·6		18 48·6	16 27·7
14	6 59·7	10 3·8	5	14 29·0	12 18·8
	16 49·9	19 59·4	6	10 9·3	8 10·0
15	12 30·2	15 50·6		19 59·5	18 5·6
16	8 10·6	11 41·8	7	15 39·8	13 56·8
	18 0·8	21 37·4	8	11 20·2	9 47·9
17	13 41·2	17 28·5		21 10·3	19 43·5
18	9 21·5	13 19·7	9	16 50·7	15 34·7
	19 11·7	23 15·3	10	12 31·0	11 25·8
19	14 52·1	19 6·5		22 21·2	21 21·4
20	10 32·4	14 57·7	11	8 11·4	7 17·0
	20 22·6	24 53·3		18 1·5	17 12·6
21	6 12·8	10 48·9	12	13 41·9	13 3·7
	16 3·0	20 44·5	13	9 22·2	8 54·9
22	11 43·3	6 40·0		19 12·4	18 50·5
	21 33·5	16 35·6	14	14 52·7	14 41·7
23	7 23·7	12 26·8	15	10 33·1	10 32·8
	17 13·9	22 22·4		20 23·3	20 28·4
24	12 54·2	8 18·0	16	6 13·4	6 24·0
	22 44·4	18 13·6		16 3·6	16 19·6
25	8 34·6	14 4·8	17	11 44·0	12 10·8
	18 24·8	24 0·4		21 34·1	22 6·4
26	14 5·1	9 55·9	18	7 24·3	8 1·9
	23 55·3	19 51·5		17 14·5	17 57·3
27	9 45·5	5 47·1	19	12 54·8	13 47·7
	19 35·6	15 42·7	20	8 35·2	9 39·9
28	5 25·8	11 33·9		18 25·4	19 35·5
	15 16·0	21 29·5	21	14 5·7	15 26·6

1888.	I. (878°·25) h m	II. (870°·27) h m
May 22	9 46·1	11 17·8
	19 36·3	21 13·4
23	5 26·5	7 9·0
	15 16·6	17 4·6
24	10 57·0	12 55·8
	20 47·2	22 51·4
25	6 37·4	8 47·0
	16 27·5	18 42·6
26	12 7·9	14 33·7
27	7 48·3	10 24·9
	17 38·4	20 20·5
28	13 18·8	16 11·7
29	8 59·2	12 2·9
	18 49·4	21 58·5
30	4 39·6	7 54·1
	14 29·8	17 49·7
31	10 0·1	13 40·9
June 1	5 50·5	9 32·1
	15 40·7	19 27·7
2	11 21·1	5 23·3
	21 11·3	15 18·9
3	7 1·5	11 10·2
	16 51·7	21 5·8
4	12 32·1	7 1·4
	22 22·3	16 57·0
5	8 12·5	12 48·2
	18 2·7	22 43·8
6	13 43·1	8 39·4
7	9 23·5	4 30·7
	19 13·7	14 26·3
8	5 3·9	10 17·5
	14 54·1	20 13·2
9	10 34·6	6 8·8
	20 24·8	16 4·4
10	6 15·0	11 55·6
	16 5·2	21 51·3
11	11 45·6	7 46·9
	21 35·8	17 42·5
12	7 26·1	3 38·2

1888.	I. (878°·25) h m	II. (870°·27) h m
June 12	17 16·3	13 33·8
13	3 6·5	9 25·0
	12 56·7	19 20·7
14	8 37·2	5 16·3
	18 27·4	15 11·9
15	4 17·6	11 3·2
	14 7·8	20 58·8
16	9 48·3	6 54·5
	19 38·5	16 50·1
17	5 28·7	2 45·7
	15 19·0	12 41·4
18	10 59·4	8 32·7
	20 49·6	18 28·3
19	6 39·9	4 23·9
	16 30·1	14 19·6
20	12 10·6	10 10·9
21	7 51·1	6 2·2
	17 41·3	15 57·8
22	13 21·8	11 49·1
23	9 2·3	7 40·4
	18 52·5	17 36·1
24	4 42·7	3 31·8
	14 33·0	13 27·4
25	10 13·5	9 18·7
26	5 54·0	5 10·1
	15 44·2	15 5·7
27	11 24·7	10 57·0
28	7 5·2	6 48·4
	16 55·5	16 44·0
29	12 36·0	12 35·4
30	8 16·5	8 26·7
	18 6·8	18 22·4
July 1	3 57·1	4 18·1
	13 47·3	14 13·7
2	9 27·8	10 5·1
3	5 8·4	5 56·5
	14 58·6	15 52·1
4	10 39·2	11 43·5
5	6 19·7	7 34·9

1888.	I. (878°·25) h m	II. (870°·27) h m	1888.	I. (878°·25) h m	II. (870°·27) h m
July 5	16 10·0	17 30·5	Aug. 11	13 38·6	13 10·6
6	11 50·5	13 21·9	12	9 19·3	9 2·1
7	7 31·1	9 13·3	13	5 0·0	4 53·6
8	3 11·7	5 4·7	14	10 31·1	10 41·0
	13 1·9	15 0 4	15	6 11·8	6 32·5
9	8 42·5	10 51·8	16	11 42·9	12 19·9
10	4 23·1	6 43·2	17	7 23·6	8 11·4
	14 13·4	16 38·9	18	12 54·7	13 58·8
11	9 53·9	12 30 3	19	8 35·5	9 50·3
12	15 24·8	8 21·7	20	4 16·2	5 41·9
13	11 5·4	14 8·8	21	9 47·3	11 29·3
14	6 46·0	10 0·2	22	5 28·1	7 20·8
15	12 16·9	15 47·3	23	10 59·2	13 8·2
16	7 57·5	11 38·7	24	6 40·0	8 59·8
17	13 28·4	7 30·2	25	12 11·1	4 51·4
18	9 9·0	13 17·3	26	7 51·9	10 38·8
19	14 39·9	9 8·8	27	13 23·0	6 30·4
20	10 20·5	14 55·9	28	9 3·8	12 17·7
21	6 1·1	10 47·4	29	4 44·5	8 9·3
22	11 32·1	6 38·8	30	10 15·7	4 0·9
23	7 12·7	12 26·0	31	5 56·5	9 48·3
24	12 43·7	8 17·5	Sept. 1	11 27·6	5 39·9
25	8 24·3	14 4·7	2	7 8·4	11 27·4
26	13 55·3	9 56·2	3	12 39·6	7 19·0
27	9 35·9	5 47·6	4	8 20·4	13 6·4
28	5 16·6	11 34·9	5	13 51·5	8 58·0
29	10 47·6	7 26·3	6	9 32·3	4 49·6
30	6 28·2	13 13·6	7	5 13·1	10 37·1
31	11 59·2	9 5·1	8	10 44·3	6 28·7
Aug. 1	7 39·9	14 52·3	9	6 25·1	12 16·1
2	13 10·9	10 43·8	10	11 56·3	8 7·7
3	8 51·6	6 35·3	11	7 37·1	13 55·2
4	14 22·6	12 22·6	12	13 8·3	9 46·8
5	9 3·3	8 14·1	13	8 49·1	5 38·5
6	5 44·0	14 1·4	14	4 29·9	11 25·9
7	11 15·0	9 52·9	15	10 1·1	7 17·6
8	6 55·7	5 44·4	16	5 42·0	13 5·0
9	12 26·8	11 31·7	17	11 13·2	8 56·7
10	8 7·5	7 23·2	18	6 54·0	4 48·3